DRAFT

REMEDIAL INVESTIGATION WORK PLAN FOR YERINGTON PIT LAKE (OPERABLE UNIT 2) YERINGTON MINE SITE

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This is a draft report and is not intended to be a final representation of the work done or recommendations made by Brown and Caldwell. It should not be relied upon; please consult the final report.

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LIST OF ACRONYMS AND ABREVIATIONS

ARC	Atlantic Richfield Company
AQM	Air Quality Monitoring
ASTM	American Society of Testing and Materials
BERA	Baseline Ecological Risk Assessment
BLM	Bureau of Land Management
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
DMP	Data Management Plan
DO	Dissolved Oxygen
DQO	Data Quality Objective
DSR	Data Summary Report
EPA	U.S. Environmental Protection Agency
FSAP	Field Sampling and Analysis Plan
GCM	Global Climate Model
GMP	Groundwater Monitoring Plan
HASP	Health and Safety Plan
HEC	Hydrologic Engineering Center
HDPE	High-Density Polyethylene
HFA	Hydrogeologic Framework Assessment
HHRA	Human Health Risk Assessment
HMS	Hydrologic Modeling Software
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectroscopy
JSA	Job Safety Analysis
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDL	Method Detection Limit
NAC	Nevada Administrative Code
NAD	North America Datum
NDEP	Nevada Division of Environmental Protection
ORP	Oxidation-Reduction Potential
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PEL	Permissible Exposure Level
PFD	Personal Flotation Device
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
QAPP	Quality Assurance Project Plan
QA	Quality Assurance
QC	Quality Control
RI/FS	Remedial Investigation/Feasibility Study
RPD	Relative Percent Difference
RPM	Remedial Project Manager
RMR	Rock Mass Rating
SLERA	Screening Level Ecological Risk Assessment
SOP	Standard Operating Procedure
SOW	Scope of Work
TDS	Total Dissolved Solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
TOC	Total Organic Carbon
USCS	Unified Soil Classification System
USFWS	U.S. Fish and Wildlife Service
XRD	X-Ray Diffraction

µg	microgram
mg	milligram
g	gram
kg	kilogram
ml	milliliter
L	liter
µm	micrometer
mm	millimeter
cm	centimeter
m	meter
ft	foot
pCi	picoCurie
µR	microRoentgen
µS	microSiemens
mV	milliVolt
M	Molar
amsl	above mean sea level
bgs	below ground surface
gpm	gallons per minute
ntu	nephelometric turbidity unit
s.u.	standard units (pH)
HNO_3	nitric acid
H_2SO_4	sulfuric acid
%	percent
^oC	degrees Centigrade

SECTION 1.0
INTRODUCTION

The Atlantic Richfield Company ("ARC") has developed this draft Remedial Investigation Work Plan for the Yerington Pit Lake ("Pit Lake RI Work Plan") pursuant to the Scope of Work ("SOW") for Operable Unit 2 ("OU2"). The SOW was attached to the Administrative Order ("Order") for Remedial Investigation and Feasibility Study ("RI/FS") for the Anaconda/Yerington Mine Site ("Site"). The Order was issued by the U.S. Environmental Protection Agency – Region 9 ("EPA") to ARC on January 12, 2007 (EPA, 2007). The Site is located adjacent to the City of Yerington, in western Nevada (Figure 1). The SOW also describes remedial investigations to be conducted by ARC and EPA for the following:

- Site-Wide Groundwater (OU-1)
- Process Areas (OU-3)
- Evaporation Ponds and Sulfide Tailings (OU-4)
- Waste Rock Areas (OU-5)
- Oxide Tailings Areas (OU-6)
- Wabuska Drain (OU-7)
- Arimetco Facilities (responsibility of EPA)

Site OUs and Arimetco facilities are shown in Figure 2 (note that OU 1 covers the entire Site and extends beyond the Site boundaries, and that EPA has not yet formally delineated all Arimetco facilities). Groundwater flow data developed from this Pit Lake RI Work Plan will be integrated with data sets from groundwater investigations developed under the: 1) draft *Remedial Investigation Work Plan for Site-Wide Groundwater (OU1)* dated June 22, 2007 (Brown and Caldwell and Integral Consulting, 2007a); 2) the *Hydrogeologic Framework Assessment North of the Anaconda Mine Site* dated April 22, 2005 ("First-Step HFA"; Brown and Caldwell, 2005a); and 3) *Second-Step Hydrogeologic Framework Assessment Work Plan* dated February 28, 2007 ("Second-Step HFA"; Brown and Caldwell, 2007). The following text (in italicized font), excerpted from Section 8.0 of the SOW, describes the framework for this Pit Lake RI Work Plan:

The purpose of the remedial investigation of the Pit Lake OU of this SOW is to characterize existing and future surface water conditions in the Pit Lake and groundwater conditions in the bedrock and alluvial flow systems in the immediate vicinity of the Pit Lake. In addition, the Pit Lake Remedial Investigation Work Plan shall identify short-term and long-term monitoring requirements for this OU. This OU is specifically related to that geographic portion of the associated RI activity described under Section 7.0 of this SOW (Site-Wide Groundwater OU). The activities in this section of the SOW also include assessing potential human health and ecological risk, and identifying portions of the Pit Lake OU that may require remediation. The collection of an adequate number of samples to satisfy the DQOs for this OU shall include the following and, as applicable, the requirements presented in Sections 1.3.4 and 1.3.5 of this SOW:

- *The physical and chemical characteristics of the pit lake on a depth-specific and seasonal basis;*
- *The physical and chemical characteristics of the bedrock and alluvial groundwater flow systems within the capture zone of the pit lake;*
- *The history, design features, operating practices and period of operation of the open pit; and*
- *Potential biological effects of the pit lake and contaminant uptake potential on both human and ecological receptors.*

The Pit Lake Remedial Investigation Work Plan shall provide an overview of the investigation strategy, a description of the tasks associated with performing the investigation, including any treatability studies, and an investigation schedule. The Pit Lake Remedial Investigation Work Plan shall identify the project team, describe investigation methodologies, describe information necessary to characterize the pit lake and associated groundwater flow systems, describe other data requirements to support any investigation methods used, provide a project management plan, reference the DMP described in Section 4.0 of this SOW, provide the investigation schedule, and describe the DQOs for the investigation. A detailed description of activities necessary to conduct a baseline human health risk assessment and screening level ecological risk assessment for the Pit Lake OU shall also be included in the Pit Lake Remedial Investigation Work Plan, which will be developed in accordance with Appendix B of EPA RI/FS Guidance. The Pit Lake Remedial Investigation Work Plan shall include, but not be limited to:

- *Specific hydrogeologic characteristics of the bedrock and alluvial groundwater flow systems within the capture zone of the Pit Lake;*
- *A description of regional and local geologic and hydrogeologic conditions affecting groundwater flow including stratigraphy, structural geology and depositional history;*
- *Identification and characterization of areas and amounts of recharge and discharge, regional and local groundwater flow patterns and characterization of seasonal variations in the groundwater flow regime;*
- *Collection of general meteorological data including, as applicable, daily precipitation and temperature records, annual and monthly precipitation averages, monthly temperature averages, wind speed and direction, evaporation rates, and climatic extremes;*
- *An analysis of topographic features that might influence the groundwater flow system including specific watershed characteristics;*
- *Structural features on pit highwalls including physical conditions and stability;*
- *Surface water flow rates from highwall springs and seeps, and an evaluation of the effect of highwall springs and seeps in surface water recharge to the Pit Lake;*
- *Pit Lake water quality including limnological data (seasonal stratification/mixing), measurements of DO, conductivity, pH, temperature, flow rate, TDS, TSS, suspended sediment, sulfate, chloride, nitrate, total and dissolved metals and radiochemicals; and*
- *Assessment of hydraulic relationships between the Pit Lake, groundwater and surface water flows in the Walker River including the development of a water balance/budget and estimate of steady-state hydrologic conditions, and determination if the Pit Lake is or will be a flow-through system or evaporative sink.*
- *The assessment should conform to proper radiation investigation protocols outlined in the "Multi-Agency Radiation Survey and Site Investigation Manual" ("MARSSIM") EPA402-R-97-016/NUREG-1575, following radiological requirements as listed in Task 1.3.4 of the SOW.*

The Pit Lake Remedial Investigation Work Plan shall also include, but not be limited to, development and implementation of ecological field surveys, installation of exploratory boreholes and monitoring wells, water quality sampling, installation and calibration of monitoring equipment, completion of treatability studies and other field tests and data analysis. Field support activities include, but are not be limited to, scheduling activities, and procurement of field equipment, office space, laboratory services and contractors. Analytical results will be *entered into the project database after appropriate QA/QC procedures are performed, pursuant to the updated QAPP and the DMP. Field activities and a summary of analytical results will be presented in a Pit Lake Remedial Investigation Report.*

Section 1.1 of this Pit Lake RI Work Plan presents relevant background information for the Site including location, physical setting and a brief description of the operational history. The investigation planning and decision-making team is described in Section 2.0. Section 3.0 integrates a description of previous pit lake investigations and resulting data, with a conceptual model for the pit lake. Sections 4.0 and 5.0, respectively, present the Data Quality Objectives ("DQO") and Field Sampling and Analysis Plan ("FSAP") for the activities described above. Upon completion of field activities, analytical results will be entered into the project database after appropriate quality assurance/quality control ("QA/QC") procedures are performed, pursuant to the updated Quality Assurance Project Plan ("QAPP") and the Data Management Plan ("DMP"), discussed further in Sections 6.0 and 7.0, respectively. Section 8.0 addresses Health and Safety aspects of the FSAP and Section 9.0 lists the references cited.

The human health risk assessment ("HHRA") and screening level ecological risk assessment ("SLERA") components of this Pit Lake RI Work Plan are provided as Appendix A and Appendix B, respectively. The Draft HHRA and SLERA Work Plans are, in large part, based on the *Revised Conceptual Site Model* (Integral Consulting and Brown and Caldwell, 2007a) dated October 5, 2007, and the information presented in the remainder of Section 1.0.

1.1 Site Location and Site Physical Setting

The Site is located about one-half mile west and northwest of the City of Yerington in Lyon County, Nevada (Figure 1). The Site is located in Mason Valley within the Walker River watershed. Agriculture is the principal economic activity in Mason Valley, typically hay and grain farming, onion production and some beef and dairy cattle ranches. Irrigation water is provided by surface water diversions from the Walker River and from pumped groundwater.

The Walker River flows northerly and northeasterly between the Site and the City of Yerington. The river is within a quarter-mile of the southern portion of the site (flood waters from the Walker River flood-plain were diverted into the pit during the January 1, 1997 flood event).

The physical setting of the Site is within the Basin-and-Range physiographic province, which is part of the Great Basin sagebrush-steppe ecosystem. Mason Valley occupies a structural graben (i.e., down-dropped faulted basin) typical of basin-and-range topography. The Singatse Range, located immediately south and east of the Site, is an uplifted mountain block. Mining and ore processing activities at the Site have resulted in modifications to the natural, pre-mining topography including a large open pit (occupied by the pit lake), waste rock and leached ore piles, and evaporation and tailings ponds.

The Site is located in a high desert environment characterized by an arid climate. Monthly average temperatures range from 33.3° F in December to 73.7° F in July. Annual average rainfall for the City of Yerington is only 5.3 inches per year, with lowest rainfall occurring between July and September (WRCC, 2007). Wind speed and direction at the Site are variable as a result of natural conditions and variable topographic features created by surface mining operations. Meteorological data collected since 2002 indicate that the dominant wind directions are to the north and the northeast (Brown and Caldwell, 2006b).

1.2 Past Mining and Dewatering Operations

Mining, milling and leaching operations for oxide and sulfide copper ores from the open pit in the southern portion of the Site were conducted between 1953 and 1978 by the Anaconda Mining Company (“Anaconda”). Figure 2 shows the locations of mine units identified at the Site, which generally coincide with the Operable Units defined in the SOW (note that the OU designations shown in Figure 2 are preliminary, and are subject to final definition by the EPA). Waste rock piles were constructed to the south and north of the open pit. Tailings impoundments and process solution evaporation ponds were constructed north of the Yerington Pit and the Process Areas, where the milling of oxide and sulfide ores took place.

The open pit was mined in 25-foot benches with an approximate 45-degree pit wall slope. Final dimensions of the mined pit were approximately 6,200 feet long, 2,500 feet wide and 800 feet deep. During mining, groundwater was encountered at approximately 100 to 125 feet below ground surface (bgs), approximately equivalent to an elevation range of 4,350 to 4,375 feet above mean sea level (amsl; Seegmiller, 1979). Anaconda installed seven large-diameter dewatering wells around the eastern perimeter of the pit margin to achieve safe mining conditions.

Initially, the depth to groundwater in these wells at the time of drilling ranged between 80 and 90 feet bgs. As mining operations deepened the pit, two additional dewatering wells were drilled inside the pit and the perimeter wells were reamed and deepened. Drilling records of these dewatering wells are very limited. Anaconda (1968) described an average pumping rate for the dewatering wells of about 3,400 acre-feet per year (afy), equivalent to about 2,107 gallons per minute (gpm) on a continuous basis.

The water pumped from the dewatering wells was used to support ore processing and related mine operations, and as a potable drinking water supply for the community of Weed Heights (U.S. Bureau of Mines, 1958). Since 1978, the Yerington Pit Lake has refilled with groundwater inflows from the bedrock and from the overlying alluvium as highwall seeps, at, or above, the alluvium-bedrock contact, and from direct precipitation. One remaining active well (WW-36) continues to supply the community of Weed Heights.

Oxide ores were crushed and leached in vats with a dilute sulfuric acid solution that was produced from an on-site acid plant ("Acid Plant"). The resulting copper sulfate solution was decanted and the remaining solids were placed in the tailings ponds. The copper sulfate solution was subjected to "iron laundering" in which the copper in solution is exchanged with iron, resulting in a copper precipitate. Residual solutions, containing elevated concentrations of iron and sulfate, were conveyed to evaporation ponds at a rate of about 700 gallons per minute (gpm) (Seitz et al., 1982).

Sulfide ores were finely crushed, and copper sulfides were recovered using a flotation process with the addition of lime to achieve a neutral pH. Residual solids were then placed in the sulfide tailings ponds. Copper concentrates from the milling process were dried and shipped offsite for smelting. Fine-grained tailings were transported to the ponds in slurry form, and the liquid fraction was recycled for use in further milling. Seepage from the northernmost tailings pond was collected in a ditch system, and recycled along with the liquid fraction of the tailings fluid. During mining and milling operations, the tailings deposition areas and associated evaporation ponds and containment ditches were progressively expanded to the north to accommodate the need for increased tailings capacity. Given the mineralogical characteristics of the ore and waste rock mined at the Site from the Yerington Pit, naturally-occurring radioactive minerals appear to have been concentrated in portions of the tailings areas and evaporation ponds and now occur as technically enhanced naturally-occurring radioactive materials ("TENORM").

Arimetco, Inc. acquired the property in 1988 from Mr. Don Tibbals, who had previously acquired the property in or about 1982 from Anaconda. Arimetco, Inc. initiated leaching operations at five lined leach pads located around the Site (Figure 2) in the following sequence: Phase I/II (1990-1997); Phase II South (1992-early 1997, plus a few months in 1998); Phase III 4X (1995-1999); Phase IV-Slot (3/1996-11/1998); and Phase IV VLT (8/1998-11/1998). Some Arimetco leach pads and solution ponds were constructed on pre-existing oxide tailings areas. Leach materials included previously deposited waste rock north of the Yerington Pit, VLT materials and ore from the MacArthur Pit. Arimetco constructed and operated an electro-winning plant with associated solution ponds located south of the former mill area (Figure 2). Arimetco ceased mining new ore and leaching operations in November 1998, and continued to recover copper from the heaps until November 1999 (EPA, 2007). Arimetco filed for bankruptcy in 1998 and abandoned the Site in 2000. From 2000 through 2004, the Nevada Division of Environmental Protection ("NDEP") managed heap process fluids by re-circulation and evaporation. In 2005, ARC was required by EPA to assume responsibility for fluid management operations at the Site pursuant to EPA's Unilateral Order for Interim Response Actions.

SECTION 2.0

PROJECT MANAGEMENT TEAM

The project management team consists of: EPA's Remedial Project Manager ("RPM") and advising technical staff; ARC's Project Manager and technical staff; and the Yerington Technical Workgroup which includes representatives from the BLM, NDEP and others. Technical staff supporting EPA, ARC, or other groups include, at a minimum, geoscientists, engineers, risk assessors, toxicologists, meteorologists, chemists, quality assurance specialists and field sampling personnel. The primary decision maker is EPA's RPM, who is responsible for reviewing and approving work plans and related documents, as well as providing guidance and suggestions for work plan implementation.

EPA's RPMs for the Site are Ms. Nadia Hollan-Burke and Mr. Dave Seter. Technical support to the EPA is provided by Mr. Steve Acree and Dr. Robert Ford with EPA's Robert S. Kerr Environmental Research Center in Ada, Oklahoma, and by EPA's subcontractors, CH2M Hill and Tetra Tech, Inc. ARC's Project Manager is Mr. Roy Thun, assisted by Mr. John Batchelder. Technical support is provided by Dr. Jim Chatham of ARC and staff from Brown and Caldwell, Integral Consulting, Inc., and Foxfire Scientific, Inc. Mr. Chuck Zimmerman is Brown and Caldwell's project manager, with technical support provided by Mr. Greg Davis, Mr. Brad Hart and Ms. Penny Bassett. Dr. Paul Jewell of the University of Utah will provide support as a limnologist familiar with the Yerington Pit Lake. Technical support on human health and ecological risk assessment issues is provided by Dr. Rosalind Schoof, Dr. Les Williams and Ms. Alma Cárdenas of Integral Consulting, Inc. and by Dr. Matthew Arno of Foxfire Scientific, Inc.

SECTION 3.0

PREVIOUS INVESTIGATIONS AND PIT LAKE CONCEPTUAL MODEL

This section of the Pit Lake RI Work Plan describes the results of the following previous investigations and data specific to the Yerington Pit Lake (listed in chronological order, with detailed references provided in Section 9.0):

- Gill (1951): *Groundwater at the Yerington Mine Site, Lyon County, Nevada*
- Seegmiller Associates (1979): *Slope Stability Affects of Pit Water Storage, Yerington Mine Lyon County, Nevada*
- Hershey and Miller (1996): *Limnology and water quality of the Yerington, Nevada porphyry-copper open-pit mine lake*
- Hershey and Miller (1997): *Geochemical modeling of the Arimetco Porphyry-Copper Open-Pit Mine Lake, Yerington, Nevada*
- PTI Environmental Services (1997): *Interim results from a study of the chemical composition, limnology, and ecology of three existing Nevada pit lakes*
- Hershey (1997): *Geochemical modeling of the Arimetco Porphyry-Copper Open-Pit Mine Lake, Yerington, Nevada*
- Atkins et. al. (1997): *Limnological conditions in three existing Nevada pit lakes: Observations and modeling using CE-QUAL-W2*
- Hershey et. al. (1998) *Analysis of sediments from a copper rich pit lake using scanning electron microscopy / energy dispersive x-rays*
- Miller and Hershey (1998): *Sulfate in Pit Lakes*
- Jewell (1999): *Stratification and Geochemical Trends in the Yerington Pit Mine Lake, Lyon County, Nevada*
- Hershey et. al. (2000): *Geochemical Model of the Arimetco Pit Lake, Yerington, Nevada*
- Hershey (2001): *Dynamics of the Yerington Pit Lake* (power point presentation)
- Hershey (2002): *Hydrology and Water Quality of the Yerington Pit Lake, Yerington, NV*
- Wiemeyer et.al. (2004): *Environmental Contaminants Program Off-Refuge Investigations Sub-Activity, Final Report, NV – Assessment of Wildlife Hazards Associated with Mine Pit Lakes*

The results of these studies, other monitoring data specific to the Yerington Pit Lake and relevant data and studies from other similar pit lakes in Nevada and other (semi-) arid states (e.g., Davis and Eary; 1997, Atkinson, 2002; Moreno and Sinton, 2002) are integrated into an updated conceptual model for the Yerington Pit Lake. Information presented in this section includes climate, geology, hydrogeology, surface water hydrology around the pit, pit water quality and spring and seep water quality and limnologic characteristics of the Yerington Pit Lake.

The data and graphics resulting from the studies listed above are summarized in Sections 3.1 through 3.3, and provided in the Figures and Appendices sections of this Pit Lake RI Work as referenced below. Electronic copies of available Yerington pit lake investigation reports are provided in Appendix C including those listed above and the Seegmiller (1979) report on pit wall stability. Additional references include information from Anaconda files stored off-site and from the University of Wyoming archives.

3.1 General Concepts

A schematic diagram of the pit lake conceptual model is provided as Figure 3-1, generally similar to that provided in the *Revised Conceptual Site Model*. This diagram illustrates the major physical, chemical and biological aspects of the Yerington Pit Lake, and is a useful reference to the following discussion. Of particular use is the concept of the pit lake water balance, and the relationship between recharge and discharge elements.

The Yerington Pit Lake continues to refill after almost 30 years since mining and pit dewatering operations ended. As described below, the pit lake surface is still below the potentiometric surface in the surrounding bedrock flow system and a cone-of-depression continues to exist around the pit (i.e., the pit lake is currently in a ‘terminal sink’ phase). The conceptual model for the recovery of groundwater into the pit lake includes the bedrock flow system as the dominant recharge source that is ultimately sourced be seepage from the Walker River. Figure 3-2 depicts the pit lake recovery curve and the range of pre-mining groundwater elevations described by Anaconda Mining Company (1968) and Seegmiller (1979).

A recent pit lake elevation of 4,212.3 feet above mean sea level (amsl) was established by survey on September 26, 2007 in conjunction with the installation of a pressure transducer and data logger to collect daily pit lake level data as part of the Second Step HFA (see Appendix E; as of November 28, 2007 the pit lake elevation was 4,212.8 feet amsl). The 3,800-foot elevation shown on Figure 3-2 is the lowest elevation of the pit floor. The recovery curve indicates that the rise in lake level is starting to flatten with time, interpreted to be a reflection of the effects of the two major water balance components (i.e., discharge via evaporation and recharge via groundwater inflows). A pit lake bathymetric map is provided as Figure 3-3.

As the pit lake begins to approach that of the surrounding potentiometric surface, which may or may not be as high as the pre-mining surface, the lake may evolve into a ‘flow-through’ phase. Potential flow-through of pit lake water into the down-gradient bedrock would likely be a seasonal effect resulting from annual precipitation and evaporation cycles and associated recharge and discharge characteristics (i.e., the pit lake water balance). During the warm summer months, the pit lake surface is heated and water is evaporated, equivalent to a pumping effect and the creation of a cone-of-depression. Up-gradient groundwater that enters the lake during the winter and spring months will replace the evaporated water, and may have the potential to raise the pit lake level sufficiently to allow pit lake water to flow into the down-gradient portion of the bedrock flow system. The hydrology of the pit lake can generally be described within the context of a simple water balance model in which water enters by groundwater or surface water inflows, and exits via groundwater outflows or evaporation, as illustrated in Figure 3-1.

Generally, lakes with large depth/area ratios, such as the Yerington Pit Lake, are less prone to deep water mixing due to the more limited effects of wind-induced currents (Lyons et al., 1994). However, this concept neglects the complex development of vertical density gradients, which can prevent deep hypolimnion water from mixing with the overlying epilimnion. Pit highwalls tend to shelter the lake surface from winds and may inhibit water column mixing by reducing wind-induced currents (Jewell, 1999).

Surface waters of the pit lake become oxygenated due to the exchange of gases with the atmosphere. However, in the deeper portion of lakes, oxygen is consumed by organic matter produced by photosynthesis at the surface and/or the oxidation of sulfide minerals at depth. The replenishment of oxygen to these deep waters is dependent on: 1) solar heat flux which warms the upper water and tends to stratify the water column; 2 vertical solute gradients which also stratify the water; and 3) wind shear stresses which tends to mix the water column.

Chemical constituents enter or leave the lake in the same manner as groundwater flow, described above, with additional sources and sinks from: 1) the dissolution of minerals due to water-rock interactions in the pit lake walls; 2) adsorption/desorption onto clays, Fe-oxides, and organic matter; 3) the formation of solid phases which become sequestered in sediment at the pit lake bottom; and 4) the settling of dust from external sources onto the pit lake surface. The solubility of many salts, metals and colloidal iron, which affect pit lake water quality, is strongly dependent on the redox state and pH characteristics of the pit lake water column. Colloidal iron strongly absorbs selenium and arsenic in oxygenated environments and will dissolve and release these elements in anoxic waters (Davis and Eary, 1997). Therefore, redox conditions in the water column will determine which metals may end up in solution when groundwater interacts with mineralized bedrock during the refilling phase. In addition, the near neutral pH characteristics of the Yerington Pit Lake will maintain iron as an oxide phase, and increase the particulate sorption capacity for metals such as selenium and arsenic.

In addition to the redox state and pH of the pit lake water column, pit lake geochemical conditions are dependent on a number of additional physical, chemical and biological processes. These are described below and include the water balance, the hydrodynamic behavior of lake waters, groundwater-wallrock interactions and evapoconcentration effects. Key concepts to be developed include the limnological and geochemical maturity of the Yerington Pit Lake after its 30-year refilling period, and whether existing pit water quality conditions are representative of future conditions.

3.2 Relevant Site and Pit Lake Conditions

This section summarizes previous pit and pit lake information including the investigations listed above. Sub-sections address Site climate and meteorology data, the geology of the open pit, and the hydrogeology, hydrology and limnology of the pit. Available water quality data for the pit lake, bedrock flow system and highwall seeps are also discussed. These data, and the general and more detailed concepts presented in Sections 3.1 and 3.3, respectively, provide the framework for the DQOs presented in Section 4.0 and the FSAP described in Section 5.0.

3.2.1 Climate and Meteorology

Huxel (1969) summarized the climate of the Mason Valley area as arid to semi-arid. Precipitation generally occurs as winter snowfall in the mountains, and summer thundershowers on the mountains and valley floor. Precipitation averages 20 inches in the mountains and 5 inches on the valley floor. Huxel (1969) cited an evaporation rate of approximately four feet, and described prevailing winds and storm trajectories that cross the valley as being generally from the west. The precipitation and evaporation data summarized by Huxel (1969) indicate a water balance strongly dominated by evaporation, resulting in a net loss condition for the valley floor and lower alluvial fan areas where the Yerington Pit is located.

The University of Utah established a portable meteorological station near the water surface on the southern access road to the lake from May 1998 to May 1999 (Jewell, 1999). The station sampled wind direction and speed and air temperature every hour. The data were stored internally and downloaded during visits to the lake (about every 6-7 weeks). A continuous meteorological record was collected for the periods from May 2 to September 18, 1998 and from December 12, 1998 to May 12, 1999. Jewell (1999) noted that the Site is located in the rain shadow of the Sierra Nevada and receives extremely low annual rainfall (5.3 inches per year) based on data from the Western Regional Climate Center (http://www.wrcc.dri.edu).

Jewell (1999) reported evaporation rates (using combined Fallon and Yerington data sets) of approximately two feet per year relative to published values of pan evaporation rates of up to five feet per year (e.g., Dingman, 1994). These data indicate that the Yerington Pit Lake is located in a strongly net evaporative area. Evaporation is directly proportional to wind velocity as well as surface air temperature, net longwave and shortwave radiation (largely a function of cloud cover), relative humidity and atmospheric pressure (Jewell, 1999). Site-specific meteorological data collected by ARC are summarized below.

Wind Direction and Speed

Wind direction and speed data have been collected at the Site since 2002. Data were collected from one wind sensor near pump back well PW-06 in the northern portion of the Site from 2002 through 2006. Since 2007, data are being collected from three sensors: AM-1 located near the haul road just beyond the western Site boundary, AM-3 located near Birch Drive just inside the eastern Site boundary, and AM-6 located between PW-06 and the northeastern Site boundary. The locations of these stations are provided in Appendix D.

Wind rose plots that illustrate combined wind direction and speed measurements are provided in Appendix E for 2005 and 2006. Wind direction at the Site is typically quite variable with no quadrant representing over 50 percent of the total measurements in a given year. When wind speeds are above 15 miles per hour (mph), however, there is a predominant wind direction from the west/southwest to the east/northeast. Bar charts that group wind measurements into wind speed classes are provided in Appendix D for 2005 and 2006. The majority (over 60 percent) of wind speed measurements during a typical year at the Site are 5 mph or less. Approximately 20 percent of the total measurements are typically between 5 mph and 10 mph. Maximum wind speeds (i.e., greater than 20 mph) typically represent about 5 percent of the measurements.

Precipitation

Precipitation data have been collected near pump back well PW-06 since 2002 and at AM-6 since 2007. Annual precipitation ranged from 1.82 inches to 6.23 inches with a mean of 3.53 inches from 2002 through 2006 as shown in Table 3-1. Precipitation data from the Western Research Climate Center COOP Station 269229 in City of Yerington is available beginning in 1914 for comparison with Site data.

Table 3-1. Precipitation and Evaporation Data					
Year	**Mine Site[1] Pan Evaporation (inches)**	**Calculated Pit Lake Evaporation[2] (inches)**	**Mine Site[1] Precipitation (inches)**	**Yerington[3] Precipitation (inches)**	**Yerington[3] Period of Record[4] Mean Precipitation (inches)**
2001	94.25	65.98	---	2.89	5.42
2002	77.53	54.27	1.82	1.80	5.37
2003	75.06	52.54	3.09	3.48	5.37
2004	102.6	71.82	3.15	3.79	5.35
2005	87.79	61.45	3.35	4.95	5.35
2006	81.07	56.75	6.23	3.19	5.32

Notes: 1) Measured near pump back well PW-06 in northern portion of Yerington Mine Site
2) Lake evaporation calculated by multiplying pan evaporation by a factor of 0.7
3) Measured at Western Research Climate Center COOP Station 269229 in the City of Yerington
4) Period of record begins in 1914 and ends with year indicated

From 2001 through 2006, annual precipitation ranged from 1.80 inches to 4.95 inches with a mean of 3.35 inches during the six year period. If the period of record is extended to include historical data back to 1914, the mean annual precipitation is approximately 5.32 inches.

Pan Evaporation

Pan evaporation data have been collected near pumpback well PW-06 since 2001, and at AM-6 since 2007. Annual pan evaporation ranged from 75.06 to 102.6 inches, with a mean of 90.49 inches from 2001 through 2006 as shown in Table 3-1. A calculated mean evaporation rate for the pit lake of 63.4 inches per year, using a factor of 0.7, is based on methods described by Dunne and Leopold (1978). Calculated annual pit lake evaporation rates range from 52 to 72 inches, which exceed precipitation values measured in the City of Yerington or at the Site.

Temperature and Relative Humidity

Temperature and relative humidity data have been collected near pump back well PW-06 since 2002 and at AM-6 since 2007. Monthly statistics for temperature, relative humidity and barometric pressure (minimum, maximum and mean values) and mean values for solar radiation are summarized in Table 3-2. Average monthly temperature at the Site typically ranges from about 30°F to 45°F in the winter months and from about 65°F to 80°F in the summer months.

Daily highs rarely exceed 95°F and daily lows rarely dip below 15°F. Relative humidity at the Site typically ranges from about 25 to 40 percent in the summer months, and 65 to 80 percent in the winter months.

Barometric Pressure

Barometric pressure data, beginning in 2005, are summarized in Table 3-2. Barometric pressure is relatively constant at the Site at approximately 867 milliBars (mBar).

Table 3-2. Summary of Site Meteorological Data

Year	Month	Count	Temperature (deg F)			Relative Humidity (%)			Barometric Pressure (mBar)			Total Solar Radiation (kJ/m2)
			Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	
2002	May	2,503	31.92	94.80	63.38	9.65	82.60	29.18				197,557
	Jun	1,657	38.09	93.20	65.55	6.61	76.60	27.38				134,730
	Jul	148	59.04	94.10	80.07	12.17	63.63	26.85				75,715
	Aug	4,495	42.76	98.70	73.10	5.25	74.40	23.74				1,601,810
	Sep	4,350	38.23	92.40	66.28	7.44	78.00	26.22				1,274,451
	Oct	4,495	19.86	81.60	51.04	7.74	93.10	34.37				991,083
	Nov	4,349	11.79	67.10	39.87	9.07	97.70	50.30				657,479
	Dec	4,495	17.68	64.88	35.13	7.65	98.30	65.75				464,798
2003	Jan	4,492	19.57	66.44	40.25	24.97	99.90	71.70				594,394
	Feb	4,060	10.11	63.22	35.87	15.00	98.30	56.60				721,898
	Mar	4,495	17.80	76.90	46.79	7.68	98.20	42.28				1,113,377
	Apr	4,350	25.09	73.10	46.50	8.48	93.60	43.11				1,314,112
	May	4,494	28.75	97.50	60.71	7.77	92.60	33.02				1,565,621
	Jun	4,349	41.83	94.00	71.56	7.27	92.50	24.94				1,756,284
	Jul	4,495	46.36	105.00	78.84	5.49	94.70	28.02				1,725,215
	Aug	4,495	47.02	95.50	74.11	6.94	97.80	33.86				1,536,406
	Sep	4,350	35.68	90.90	67.02	6.65	82.60	27.94				1,261,469
	Oct	4,495	25.89	85.20	57.87	6.52	96.80	33.08				1,020,227
	Nov	4,350	11.96	69.30	37.82	15.43	98.30	61.49				595,283
	Dec	4,313	8.66	61.56	35.26	13.55	98.30	65.58				457,534

Table 3-2. Summary of Site Meteorological Data - Continued

Year	Month	Count	Temperature (deg F)			Relative Humidity (%)			Barometric Pressure (mBar)			Total Solar Radiation (kJ/m2)
			Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	
2004	Jan	4,310	6.68	57.80	32.66	24.49	98.10	66.96				579,433
	Feb	4,205	14.61	60.30	36.85	20.77	98.50	60.28				672,672
	Mar	4,302	27.56	80.00	51.80	8.57	98.40	41.28				1,142,320
	Apr	4,350	26.36	82.70	52.85	7.65	95.50	33.92				1,411,176
	May	4,495	34.66	88.30	61.16	6.88	92.70	30.36				1,746,250
	Jun	3,884	39.12	91.10	70.31	4.86	79.40	25.86				1,539,165
	Jul	4,495	50.50	99.10	77.06	6.05	86.80	26.81				1,737,847
	Aug	4,436	44.63	97.50	72.19	7.90	94.10	31.20				1,017,890
	Sep	3,701	30.93	93.40	63.14	7.54	82.40	28.15				544,911
	Oct	4,464	26.13	81.90	50.95	8.40	96.80	48.67				423,489
	Nov	2,559	-6.42	62.36	32.13	21.07	98.00	69.00				178,566
	Dec	4,464	-5.80	57.23	30.01	13.65	98.20	79.39				242,796
2005	Jan	3,497	10.65	46.41	29.86	38.43	99.60	86.65	861.00	884.00	873.80	208,513
	Feb	2,688	20.20	57.84	36.45	12.75	98.80	80.25	856.00	883.00	867.83	274,536
	Mar	2,976	23.48	73.20	45.22	8.88	94.80	46.77	851.00	880.00	867.34	575,543
	Apr	2,880	23.98	75.70	49.16	7.55	95.60	41.25	854.00	875.00	865.70	675,317
	May	2,976	33.98	84.40	59.38	10.10	93.40	46.45	854.00	872.00	865.03	756,679
	Jun	2,876	32.82	89.40	64.26	5.16	90.40	34.41	855.00	870.00	863.50	877,418
	Jul	2,960	50.99	100.30	79.23	7.01	79.00	28.27	861.00	872.00	867.11	871,297
	Aug	2,976	45.88	96.00	74.85	5.19	76.20	28.09	860.00	872.00	867.36	800,248
	Sep	2,880	34.30	90.70	61.70	6.85	84.50	32.74	857.00	877.00	867.54	649,055
	Oct	2,976	29.10	81.50	53.06	8.77	94.60	43.49	858.00	881.00	868.15	471,360
	Nov	2,880	14.68	76.60	43.00	11.95	95.90	47.26	858.00	882.00	870.87	338,604
	Dec	2,976	11.72	62.93	36.10	13.75	97.00	72.26	848.00	881.00	869.96	197,111
2006	Jan	2,959	16.30	58.01	35.66	24.98	96.30	67.04	851.00	883.00	870.23	241,836
	Feb	2,688	8.57	62.75	36.33	11.56	95.10	59.92	851.00	882.00	869.95	398,432
	Mar	2,976	17.37	66.45	38.75	12.68	96.60	55.07	849.00	874.00	862.24	508,970
	Apr	2,880	23.16	78.00	50.16	11.22	93.20	49.70	852.00	875.00	864.19	658,272
	May	2,976	30.21	87.80	61.85	7.54	82.30	33.87	853.00	874.00	866.31	847,384
	Jun	2,880	40.23	97.50	72.17	6.91	76.70	27.92	857.00	874.00	867.48	844,672
	Jul	2,939	51.50	99.40	78.80	7.47	89.30	29.19	861.00	874.00	868.00	820,480
	Aug	2,976	44.41	95.20	72.68	4.50	71.20	23.93	862.00	873.00	866.88	828,414
	Sep	2,843	30.47	91.30	64.06	7.91	69.44	27.15	854.00	875.00	867.88	626,507
	Oct	2,976	22.45	77.30	50.13	8.14	93.40	42.41	856.00	883.00	868.21	501,150
	Nov	2,880	9.26	75.40	42.14	9.01	97.20	48.74	857.00	881.00	869.13	295,364
	Dec	2,939	-1.02	59.96	29.90	10.67	95.30	60.36	853.00	884.00	872.64	249,853

Solar Radiation

Solar radiation data have been collected near pump back well PW-06 since 2002 and at AM-6 since 2007. Monthly totals of solar radiation are provided in Table 3-2. Total monthly solar radiation at the Site ranges from approximately 200,000 kiloJoules per square meter (kJ/m^2) in the winter to approximately 900,000 kJ/m^2 in the summer.

3.2.2 Pit Geology

The Yerington open pit mine was developed in a Jurassic-age quartz-monzonite porphyry (part of the composite Yerington batholith) that intruded a thick sequence of Triassic-age metamorphic rocks, composed of various meta-volcanic and meta-sedimentary units (Wilson, 1963). This area of economic copper mineralization is located at the base of the Singatse Range on the west side of Mason Valley, a structural basin surrounded by uplifted mountain ranges common to the Basin-and-Range physiographic province.

The uplifted mineralized bedrock was covered with distal alluvial fan materials (the open pit has an exposed thickness of alluvium up to 170 feet). Based on lithologic logging of borehole data from the Process Areas of the Site (Brown and Caldwell, 2006a), located 1,500 feet north of the open pit, the alluvial materials overlying the copper ore body include alluvial fan, transitional, and fluvial depositional facies (transitional facies also includes lacustrine deposits from Pleistocene Lake Lahontan). These deposits are interbedded in a complex fashion and result from uplift and erosion of the Singatse Range, lake deposits formed in Pleistocene Lake Lahontan, and the fluvial depositional setting associated with the Walker River.

The geometry of the porphyry copper ore body was elongated in a N 60^{o}W direction, approximately 6,000 in length, and 2,200 feet in width at its eastern exposure and 1,000 feet in width at its western margin (Wilson, 1963). The porphyry consisted of a complex series of igneous intrusions with grano-diorite and quartz-monzonite on the north, grano-diorite and a variety of other igneous lithologic types on the south, and tonalite on the west (Wilson, 1963). The porphyry was cut by a number of Tertiary-age, post-mineral rhyolite and andesite dikes, a common expression of bi-modal volcanism in the western Nevada.

The distribution of copper ore generally conformed to the geometry of the porphyry, with a maximum thickness of 800 feet in cross-section (Wilson, 1963). High-grade ore in the central portion of the deposit was composed of chalcopyrite with pyrite as the other important sulfide mineral. Minor bornite, covellite and chalcocite also occurred as secondary sulfides. Sulfides were noted to occur as minute, discrete grains in the groundmass and phenocrysts (larger crystals) of the porphyry. The oxidation front in the deposit was generally distinct and somewhat undulating. Its maximum vertical extent was along the eastern portion of the deposit where essentially all sulfides had been oxidized.

Copper mineralization did not appear to have been cut-off or lost due to post-mineral basin-and-range style faulting (Wilson, 1963). The host rocks were cut by a series of shear zones that were oriented parallel to the long axis of the porphyry (N 60^{o}W), or that trended in a north-south direction. After emplacement of the porphyry and associated copper mineralization, the deposit was subjected to tilting approximately 55^{o} as a result of complex Basin-and-Range style extensional (i.e., listric) faulting. If re-constructed prior to mining, the Yerington copper deposit would have appeared as a steep, southeast-plunging ore body, suggesting an original vertical extent of copper mineralization of over 4,000 feet (Wilson, 1963). Proffett (1977) noted that at least 100 percent of structural extension in an east-west direction due to Basin-and-Range faulting occurred in the area of the Yerington Mine Site, with the greatest rate of extension between 11 and 17 million years before present. Dilles and Gans (1995) noted at least 150 percent of structural extension younger than 15 million years before present.

Proffett and Dilles (1984) published a geologic map of the Yerington Mining District, and a portion of this map that presents the general geology of the open pit is reproduced as Figure 3-4. The geologic map shows three major igneous rock types of the Yerington batholith, and a small sliver of Tertiary volcanic and volcaniclastic rocks in the northwest corner of the pit. The internal structure of the igneous rocks exposed within the pit appears to be generally oriented along the long axis (northwest orientation) of the pit.

Geologic cross-sections (A-A' and C-C') through the Yerington Pit from Proffett and Dilles (1984) are reproduced as Figures 3-5 and 3-6, respectively. The pit area is shown in relation to the major structural features at the site on section A-A'. These faults generally strike to the north and dip to the east. The Range Front Fault, shown on the eastern side of section A-A', occurs between the open pit and the Walker River. The Sales Fault bounds the western margin of the structural block that contains the pit, and exhibits a large degree of rotation as evidenced by the stratigraphy of the Tertiary volcanic rocks against the fault (Proffett and Dilles, 1984). Low-angle faults (Singatse and May Queen Faults) appear to form a structural bottom to the block that contains the pit, also depicted on section C-C'.

Structural Elements

A map of structural elements within the pit was prepared by Seegmiller (1979) for the Anaconda Mining Company as part of a rock mechanics and slope stability study to determine the physical stability of the Yerington Pit walls during and after groundwater refilling of the pit. This map is reproduced in this Pit Lake RI Work Plan as Figure 3-7. Seegmiller (1979) identified one major structural feature with a strike length of approximately 3,000 feet, the Sericite Fault, in the pit. The strike of the Sericite Fault varies from east to northeast with dips approximately 50^{o} to 70^{o} to the north and northwest, parallel or sub-parallel to a number of minor faults up to 1,200 feet in length exposed in the eastern portion of the pit. The western portion of the pit also exhibits minor faults that generally strike east to northeast with moderate to steep dips (45^{o} to 90^{o}). Pit geology and the major structural elements depicted in Figures 3-4 and 3-7, respectively, along with current groundwater elevation data described below, provide the basis for groundwater investigations described in Section 5.0 of this Pit Lake RI Work Plan.

Seegmiller (1979) observed that, at any given location within the pit, three major joint sets occur. The major joint sets may be accompanied by one or two moderate and up to three minor joint sets in many places. Given the numerous joint sets, the igneous rocks within the pit that hosted the copper ores were broken into blocks with an average size of 4 to 6 inches.

Pit Slope Stability

Seegmiller (1979) study analyzed the physical stability of the Yerington Pit walls during and after groundwater refilling of the pit, and reached the following conclusions:

- *Slope Failure Mode* – The failure mode, or type of slope failure, will predominately be the circular soil type which has historically occurred at Yerington. Such slope failures will include headwall tension cracks at distances of several hundreds of feet beyond the actual slope failure. There will be slumping and subsidence between the pit and the outermost tension cracks. Both vertical and horizontal movement will take place.
- *Slope Failure Initiation* – Signs of instability will probably become evident prior to the water level reaching the half-full condition at elevation 4120. Such instability is most likely to occur along the north slope of the pit.
- *Slope Failure Rate* – The rate of slope failure will be directly related to the rate at which water enters the pit. At the half-full water condition, the safety factors are most probable at values slightly less than 1.00 or the theoretical beginning point of failure. In other words a major disequilibrium does not exist, only a minor disequilibrium. Therefore at the half-full water condition the failure rate should be relatively slow as it has historically been. At the full water condition the safety factor drops to a magnitude of 0.80 in the north central zone which would indicate a higher failure rate than at the half-full water condition. The failure rate would probably still be relatively slow, but it would probably be faster than observed historically. In summary it is believed that catastrophic slope failure would occur with less than a 5 percent probability unless the pit is filled with water over a very short period of time such as two months of less.
- *Slope Failure Extent* – The extent of potential slope failure has been examined in terms of the probability of its occurrence. In general, the practical limit of slope instability and related surface disruption is on the order of 1200-1300 feet beyond the present pit crest. Related problems beyond the distance are believed to have less than 1 percent probability of occurrence. The worst case is in the north central zone of the pit and the best case is in the east end of the pit, where any instability affects should be limited to within 400 feet of the crest. The leach dumps in back of the north central portion of the pit appear to have about a 20 percent probability of being involved in a slope instability at the full water condition. Such instabilities in the leach dump should, from a practical standpoint, not be so great that if their occurrence appears imminent, effective remedial action could be implemented to alleviate or minimize the problem.

The initiation of slope failure after the pit lake level has reached its halfway point, as presented in the second bullet, has not occurred to date based on empirical observations. However, the potential for slope failure and related geotechnical issues will be evaluated as part of the FSAP described in Section 5.0 of this Pit Lake RI Work Plan.

Oxidation, Mineralogy and Alteration

The orebody developed by Anaconda was considered by Wilson (1963) to be one of the few copper porphyry deposits where geologic conditions were optimum for the formation of an important economic concentration of oxide ore and a minimum economic secondary enrichment. The lower limit of oxidation is sharp and distance and re-deposition of oxidized copper products is considered to have occurred for the most part *in-situ.* The principal oxidation product was chrysocolla, which occurred irregularly dispersed throughout the rock and as narrow seams along fractures. Locally, clay-altered phenocrysts of the porphyry contain sufficient finely divided chrysocolla to constitute important ore. Cuprite, tenorite and melaconite all were widely distributed, with local occurrences of malachite and azurite (Wilson, 1963).

The transition zone between the oxidized and unoxidized portions of the orebody included chalcocite, cuprite, melaconite, native copper and chrysocolla. Immediately underlying the transition zone, the primary sulfide minerals, pyrite and chalcopyrite occurred as minute grains in the groundmass of the porphyry, in feldspar and quartz phenocrysts, and as narrow seams. Generally, chalcopyrite was slightly more abundant than pyrite. Small amounts of bornite and covelite were present, and primary chalcocite was detected microscopically (Wilson, 1963).

Sodium-calcium metasomatism affected more than one-third of the altered granitic rock associated with the Yerington orebody (Carten, 1986). This type of alternation is: 1) characterized by the conversion of primary minerals to more sodium- and/or calcium-rich minerals including K-feldspar to oligoclase, and biotite to actinolite; and 2) distinct from propylitic alteration, in which albite is formed principally by the loss of calcium from plagioclase, not by the metasomatic addition of sodium. Except for the presence of this alteration type, alteration and mineralization assemblages at the Yerington mine are similar to those observed at other porrhyry copper deposits where potassic alteration dominates and is overprinted by sericitic alteration (Carten, 1986).

3.2.3 Pit Area Hydrogeology and Hydrology

Gill (1951) summarized groundwater conditions in the proposed open pit area (e.g., groundwater inflow and dewatering rate estimates), as summarized below:

- Pumping tests for 10 months in 1945 in the range of 1,000 to 1,400 gpm indicated that: 1) inflows from outside the basin (i.e., derived from the Walker River) would be in the 1,200 to 1,400 gpm range and account for 85 percent of the pumped water, and 2) the remainder of the pumped water would be derived from within the basin (i.e., derived from Singatse Range recharge, 200 gpm if the pit floor was lowered 50 feet per year);
- The recovery of groundwater after test pumping ceased indicated that the major source of water inflows was located south and east of the proposed open pit, and little water from the west;
- The Walker River was considered to be the major source of inflows, and the concept of intercepting these inflows at a location east of the pit was proposed to reduce pumping costs and potential interruptions to mining;
- Ultimately, the largest degree of uncertainty associated with pit dewatering focused on the permeability of the fractured bedrock associated with the orebody, and its connection to recharge from the river;
- Specific locations (i.e., 'fissures') within the orebody were identified as being 'permeable'

Dewatering of the Yerington Pit to support mining operations beneath the pre-mining potentiometric surface of approximately 4,350 to 4,375 feet amsl (Anaconda Mining Company, 1968 and Seegmiller, 1979) required the use of perimeter wells (Figure 3-8). As described above, some of the in-pit and perimeter dewatering wells were initially constructed or deepened to depths below the ultimate pit bottom (3,800 feet amsl) in order to maintain a "dry" pit through the end of mining operations. Although little information is available for individual wells used to dewater the pit, the combined average production rate of up to 2,100 gpm was adequate to allow open pit mining to advance to the 3,800-foot elevation.

<u>Hydrogeology</u>

The range of reported pre-mining groundwater elevations is not uncommon in fractured bedrock flow systems where clay-filled faults can compartmentalize groundwater flow into discrete hydrogeologic blocks. Seegmiller (1979) noted that perched groundwater was a common occurrence in most of the pit slopes. Although, on the scale of the pit, the fractured granitic bedrock transmits groundwater as an effective porous media, discrete structural elements in the Yerington Pit will likely influence groundwater inflows. Typically, groundwater flow is: 1) impeded across clay-bearing or clay-rich faults and flow is enhanced along the strike of structures that exhibit brittle fracture (with open spaces); and 2) enhanced along brittle fracture or fault zones characterized by open spaces. The concept of groundwater being locally compartmentalized is supported by the geologic map (Figure 3-4) and the map of pit structural elements (Figure 3-7).

Figure 3-9 depicts a conceptualized cone-of-depression around the pit lake, based on July 2007 groundwater elevation measurements in nearby monitor wells and the September 2007 surveyed elevation of the pit lake surface (see Figure 3-10). The geometry of the conceptualized cone-of-depression infers that isotropic rock mass and hydraulic conductivity conditions occur in the fractured bedrock aquifer around the pit. Although isotropic conditions are not expected because of compartmentalized groundwater flow in the fractured and altered bedrock, the conceptualized cone-of-depression around the pit lake illustrated in Figure 3-10 provides a basis for groundwater investigations to be conducted, as described in Section 5.0 of this Pit Lake RI Work Plan.

Well WW-36, a former dewatering well constructed in the bedrock, is an active pumping well that supplies water to Weed Heights for municipal and industrial use. However, because it is a pumping well, a static water elevation cannot be measured in WW-36 for comparison to the pit lake surface. The 400 gpm on-demand pumping rate from WW-36, and the approximate annual extraction rate of 29.2 million gallons based on flow totalizer readings (Don Tibbals, pers. comm., 2007), are important components of the pit lake water balance.

<u>Interpretation of Groundwater Flow in the Area of the Pit Lake</u>

Appendix E includes a photograph of the bedrock-alluvium contact below the community of Weed Heights at the west margin of the pit. A portion of this contact appears to be submerged under the current pit lake elevation of approximately 4,212 feet amsl. Although the current depth of submergence, and the timing of the pit lake surface rising to the elevation of the contact, cannot be precisely determined, it appears that this condition developed over the past 2-3 years based on the geometry of the bedrock-alluvium contact and the recent rate of pit refilling described above. At this location, the pit lake has the potential to recharge this portion of the alluvial groundwater flow system west of the pit.

A north-south hydrogeologic cross-section through the open pit that extends past northern boundary of the Site (Figure 3-10) has been developed based on available data from recent field activities associated with routine groundwater monitoring and Second Step HFA field investigations. This generalized cross section, with 10x vertical exaggeration, illustrates the relationship between the bedrock and alluvial groundwater flow systems, groundwater elevations (measured in July 2007) and the surface of the Yerington Pit Lake (surveyed in September 2007). In general, groundwater in the alluvial aquifer flows to the north, with localized flow into the pit lake, which may create a groundwater divide north of the pit lake in the alluvial aquifer. The limited portion of the bedrock groundwater flow system depicted in Figure 3-10 flows into the pit lake, which is conceptualized to be ultimately sourced from the Walker River seepage.

Note that the plane of the cross-section in Figure 3-10 does not intercept a mapped fault-contact between the alluvium and the bedrock, and that the precise geometry of the alluvial bedrock contact is unknown along the plane of the cross-section. The cross-section does not reflect the potential recharge into the alluvial aquifer at the western margin of the pit described above. As seen in Figure 3-10, the groundwater elevation in B/W-13 is higher than other alluvial groundwater elevations, and represents recharge from the Walker River to the Site. Alluvial groundwater elevations within the Site boundary from PAMW-3 to MW-5 decrease seven feet over a distance of 6,750 feet, a relatively flat gradient of 0.001 feet per foot (note that the monitor wells located north of the Site are constructed in the deep alluvial aquifer).

In summary, the area of the pit lake is geologically and hydrologically complex, although groundwater elevations in the bedrock and alluvium surrounding the Yerington Pit Lake generally appear to be consistent with a refilling pit lake recharged by the alluvial and bedrock flow systems. The majority of the recharge is conceptualized to occur from the Walker River to the east of the pit, as indicated by the dashed potentiometric surface from B/W-13 to the pit lake. The dashed potentiometric surface from alluvial well PAMW-3 to bedrock well WW-59 to the lake suggests that a hydraulic connection between the alluvium and bedrock exists in this area, and that a groundwater divide, at least in the alluvium and potentially in the bedrock, may exist north of the pit lake. In addition, the submergence of the alluvium-bedrock contact at the western margin of the pit is anticipated to result in pit lake outflows into this portion of the alluvial aquifer. These aspects of groundwater conditions in the area of the Yerington Pit Lake will be evaluated as part of this Pit Lake RI Work Plan.

Hydrology

Exposure of the alluvium within the highwalls of the Yerington Pit caused some portion of groundwater flow in the alluvial fan to flow into the pit as a series of seeps, as seen at the present time along the western margin of the pit. Seegmiller (1979) noted that groundwater along the bedrock-alluvium contact at the west end of the pit was normally encountered during mining. Similarly, minor flows in to the pit from the eastern highwall alluvium likely occurred.

Inflows at the west end of the pit from the alluvial aquifer along the bedrock-alluvium contact have been measured at rates up to approximately 50 gpm (Hershey, 2002). It is not known how much of this inflow results from water losses associated with businesses and residential units in Weed Heights, as suggested by observed nitrate concentrations in this highwall spring. Hershey (2002) measured seepage from the Walker River through the alluvium at the east margin of the pit at rates of approximately 100 to 120 gpm. Current photographs of these seeps are provided in Appendix E. At the present time, the east wall seep is the only surface water inflow that can be accessed by foot.

The eastern edge of the pit is about 1,200 feet from the Walker River. Prior to the flood of January 1, 1997, limited seepage from the Walker River was observed in the alluvium on the east highwall. An inferred range front fault mapped by Proffett and Dilles (1984) between the open pit and the river, shown in Figure 3-2, may have impeded recharge from the river to the alluvial aquifer directly adjacent to the pit, thus limiting flow directly into the pit). This natural boundary condition was modified by Arimetco mining crews, along with crews from Tibbals Construction and the Fallon Naval Air Station, during the January 1997 flood event (Mason Valley News; January 10, 1997). This emergency flood management diversion, implemented to limit flood damage to the City of Yerington and maintain regional power supply infrastructure, required State and Federal approval, and a signed court order by Lyon County District Court Judge Blake.

The initial narrow channel diversion between the river and the pit was immediately enlarged by flood waters, as documented in a photograph in the special edition of the Mason Valley News (January 10, 1997). The current geometry of the eroded cut in the highwall is generally similar to that documented in 1997 (Appendix E). Since the diversion was created, flow rates into the pit from this east highwall spring have been measured at seasonably variable rate between 100 and 120 gpm (Hershey, 2002). Aside from the flow and chemical data presented herein for highwall seeps, other aspects of pit hydrology are not available (e.g., the capture area of the pit for direct precipitation and surface water runoff).

Note that the concept of Walker River recharge to the bedrock flow system in the immediate area of the open pit as indicated by Gill (1951), and other hydrogeologic information described above, may appear inconsistent with information provided by Hershey (2002), described below. Hershey (2002) described the occurrence of a mapped range-bounding fault (inferred location shown in Figure 3-4) that prevented seepage from the alluvial highwall into the open pit during mining. The degree of hydraulic connectivity between the river and the bedrock flow system is currently uncertain, and select FSAP activities described Section 5.0 will focus on this concept.

Interpretation of the Pit Lake Hydrograph

The hydrograph in Figure 3-2 is the pit lake recovery curve for the period from the cessation of mining in 1978 through the present. The hydrograph indicates that the pit lake level continues to refill and is currently over 400 feet deep. The surveyed pit lake elevation of 4,212.3 feet amsl as of September 26, 2007 is approximately 110 to 160 feet below the pre-mining bedrock groundwater elevation range of 4,350 to 4,375 feet amsl (Seegmiller, 1979). For the three time increments from 1989 to 1996, from 1997 to 2001, and from 2002 to the present, pit levels rose at an average rate of 5.9, 7.6 and 4.7 feet per year, respectively. The increased recovery rate in early 1997 is attributable to the diversion of Walker River flood waters in January 1997.

ARC recognizes that vertical survey controls for pit lake surface elevation measurements may not have been consistent over the past 20 years due to the use of different surveyors. Such potential inconsistencies may limit the precision of the pit lake hydrograph. However, the general shape of the Yerington Pit Lake recovery curve is consistent with other modeled or measured pit lakes after dewatering operations end (e.g., Moreno and Sinton, 2002; Atkinson, 2002), and provides the framework for the conceptual model of the Yerington Pit Lake. The installation of the pressure transducer and data logger in the pit lake, and a consistent survey control base, will improve the reliability of the pit lake hydrograph for future decision making.

During the refilling phase, the pit lake surface is lower than the surrounding potentiometric surface in the bedrock groundwater flow system and the pit lake is: 1) considered to be a 'terminal sink', where groundwater flows into the lake but not out because the lake level is lower than the surrounding potentiometric surface in the bedrock; and 2) analogous to a pumping well after the pump is shut off with a refilling 'cone-of-depression'. However, the recent interception of the pit lake surface with the bedrock-alluvium contact at the western edge of the pit has the potential for pit lake water to recharge the alluvial aquifer in this area.

The pit lake hydrograph in Figure 3-2 yields the following information: 1) initial groundwater inflows up to, and including, the early 1980s, represents the highest refilling rate; 2) the effect of the 1997 flood diversion, which instantaneously increased the pit refilling rate, is reflected in the hydrograph; 3) the refilling rate appears to have decreased since about 2000 to 4.7 feet/year relative to the pre-flood pit filling rate of 5.9 feet/year, conceptualized to be the result of increased evaporative losses from the increasing surface area of the pit lake; and 4) the September 2007 pit lake surface measurement supports the decrease in the recovery rate and the flattening of the recovery curve. A reasonable projection of how this balance between groundwater and surface water inflows, and losses due to evaporation, is depicted in Figure 3-11 (an extension of the hydrograph to 2050), where the recovery curve is projected to asymptotically flatten over time, based on a second-order polynomial trend line for the available data. This projection indicates that hydraulic "steady-state" conditions may occur during the time period from 2015 to 2020 when the surface elevation of the pit lake does not increase beyond the upper range anticipated by seasonal fluctuations in lake level.

"Steady-State" Conditions

The concepts of the pit lake water balance and hydraulic "steady-state" conditions are significant for the characterization of existing conditions and the prediction of future, respectively, because of hydraulic controls on pit lake hydrodynamics and water quality. The "steady-state" condition is defined as the hydraulic condition when mean annual, or longer period, outflows equals inflows. The equilibration of pit lake levels relative to inflows (i.e., groundwater recharge, surface water seeps and runoff, and direct precipitation) and outflows (groundwater outflows and evaporative losses) would be characterized by a relatively constant lake level in perpetuity. Minor fluctuations in response to seasonal effects (e.g., winter and spring recharge followed by summer evaporative losses), or longer period effects when climatic events (e.g., extended drought periods) or unusual surface water inflows (e.g., flood events) temporarily disrupt the mean annual cycle, would affect a relatively constant pit lake level for a finite period of time. Anticipated hydraulic "steady-state" conditions would result in limnological (e.g., lake turnover) and geochemical (e.g., evapoconcentration) processes that should be repeated on an annual basis.

3.2.4 Pit Limnology

Data, graphics and interpretations of the data by the authors of several investigations of the limnology of the Yerington Pit Lake are provided in the reports in Appendix C. Atkins et. al. (1997) summarized the limnology of the Yerington Pit Lake as:

- Seasonally stratified with respect to temperature (i.e., exhibits a thermocline in the summer and late fall that separates an upper epilimnion from the hypolimnion, at depth);
- Well-oxygenated;
- Oligotrophic (i.e., low biological productivity);
- Having a relatively large depth-to surface area ratio; and
- Holomictic (i.e., it is completely mixed during one or more winter turnover events).

Jewell (1999) reported that the Yerington Pit Lake behaves very similar to natural lakes at mid-latitude locations, with a seasonal thermocline that develops in the spring and a maximum surface temperature (approximately 25^{o}C) in the late summer and fall. Hypolimnitic water, below a depth of approximately 130 feet, was observed to have a relatively uniform temperature of 6.2^{o} to 6.5^{o}C. In January 1999, Jewell (1999) observed that the pit lake had a uniform temperature of approximately 6^{o}C, indicating that turnover probably occurred sometime in late 1998. Jewell (1999) suggested that the lake is monomictic (i.e., it mixes once during the coldest portion of the year), but also indicated that mixing may occur several times over the winter months, which is consistent with the description by Atkins et. al, (1997). Jewell (1999) noted that the fact that deep water oxygen depletion was not greater in 1998 than it was in previous sampling years is additional evidence that the lake turns over on an annual basis.

Because of its depth, the hypolimnion of the Yerington Pit Lake is a large dissolved oxygen (DO) reservoir capable of oxidizing organic matter from the epilimnion, and is less likely to become anoxic. Jewell (1999) concluded that the Yerington Pit Lake "will not permanently stratify in any plausible future climate scenario and will remain oxygenated over the next several decades. Long-term stratification is precluded by relatively low concentrations of dissolved solids in groundwater and the small amount of surface water entering the lake". The evolving and "steady-state" limnology of the pit lake will, in conjunction with the chemical concentration of groundwater inflows, provide the framework for the assessment of long-term pit water quality.

Jewell (1999) noted that the development of anoxia in a lake is dependent on the amount of available nutrients (phosphorus, nitrogen, and various trace elements such as iron and copper) as well as the ability to exchange oxygen with the atmosphere. Primary productivity of most lakes is considered to be phosphorous limited (i.e., phosphorous is the first element to be depleted during photosynthesis, and limits the amount of biological productivity), and most lake eutrophication models are based on phosphorous loading (e.g., Schindler, 1977).

3.2.5 Pit Water Quality

Groundwater and surface water quality data associated with the Yerington Pit are available from the following locations sampled during previous investigations:

- Groundwater dewatering/production wells completed in the bedrock aquifer (WW-36, WW-40 and WW-59);
- Groundwater monitor wells completed in the alluvial aquifer (B/W-13, B/W-14 and B/W-15);
- Seeps along the east and west pit margins that flow into the pit lake; and
- Pit water from various depths (surface to about 340 feet below the surface of the pit lake).

Former dewatering and production wells WW-36, WW-40 and WW-59 are screened in bedrock and currently used for routine groundwater monitoring. As previously noted, WW-36 currently serves as the water supply well for the community of Weed Heights. Wells B/W-13, B/W-14 and B/W-15 are screened in alluvium and are currently used for routine groundwater monitoring.

Information relevant to pit area water quality described herein is presented in Appendix F. Available chemical data from the groundwater and surface water inflow sources, and from the pit lake, are summarized in Appendix F-1. Note that not all chemicals to be evaluated pursuant to this Pit Lake RI Work Plan have been analyzed during previous investigations conducted by others. The available data indicate that, in general: 1) water quality (dissolved constituent analyses) in the bedrock and alluvial aquifers in the vicinity of the pit is generally good; and 2) concentrations of constituents in groundwater from the bedrock and alluvial aquifers in the vicinity of the pit are generally similar to concentrations found in the pit lake.

Available chemical data in Appendix F for the seeps located on the west and east sides of the Yerington Pit also indicate generally good water quality (particularly the east spring that is sourced directly from the Walker River, as discussed further below). The seep located on the west side of the Yerington Pit (i.e., directly beneath Weed Heights) occasionally exhibits relatively high nitrate concentrations. The source of nitrate in this spring may be agricultural or lawn maintenance practices and/or seepage from sewer systems associated with the community of Weed Heights. Other highwall seeps have not been sampled and analyzed during previous investigations. However, based on empirical observations, these other seeps contribute minimal flows to the pit lake, and, thus, will not be monitored pursuant to this Pit Lake RI Work Plan. Analytical results for pit wall or access ramp runoff are also not available.

Information supporting the conceptual geochemical model elements for the Pit Lake OU includes: 1) a trilinear diagram illustrating the major ion compositions of identified water types (Appendix F-2); 2) box plots for select chemicals in pit lake waters, the west and east seeps, alluvial and bedrock monitor wells near the pit lake, and the Walker River (Appendix F-3); 3) pit lake hydrographs and time-concentration plots (Appendix F-4); and 4) charts illustrating the concentrations of select chemical in the pit lake as a function of depth (Appendix F-5). The following description of select chemicals observed in groundwater and surface water associated with the Pit Lake OU is based, in part, on the information provided in Appendix F and the previous investigations described above (specific discussions of copper and selenium are included because of their concentrations in excess of select water quality standards).

General Chemistry

The major composition of samples of pit lake water, seeps, alluvial and bedrock groundwater and the Walker River are shown on the trilinear diagram presented in Appendix F-2 and in box plots presented in Appendix F-3. As indicated in the trilinear diagram, water in the pit lake has a predominantly calcium-sulfate-bicarbonate (Ca-SO_4-HCO_3) composition. The major cations (Ca, Mg, Na and K) in the Yerington Pit Lake do not vary significantly on either a temporal or spatial (depth) basis (Jewell, 1999). Likewise, bicarbonate (the dominant component of alkalinity for waters of the near neutral range of pH values observed in the pit lake), sulfate, and chloride do not vary significantly on either a temporal or spatial (depth) basis (Jewell, 1999). As indicated in the pit lake hydrograph and time-concentration plots (Appendix F-4), concentrations of chloride and sodium in water samples collected at depths of 0 to 1 m appear to be increasing slightly over time, and concentrations of sulfate appear to be decreasing slightly over time.

Inflows to the pit lake from the west (including the west spring, bedrock monitor well WW-59, and alluvial monitor well B/W-13) have a major ion composition that is similar to the major ion composition of the pit lake. Inflows to the pit lake from the east (including the east spring, bedrock wells WW-36 and WW-40, and alluvial well B/W-15) have a predominantly calcium-bicarbonate ($Ca\text{-}HCO_3$) composition that is similar to the major ion composition of the Walker River.

<u>pH Values</u>

As shown in the data and graphics provided in Appendix F, pit lake water is neutral to slightly alkaline. Although pH as low as 6.2 is recorded in upper hypolimion of the spring/summer lake waters, the vast majority of pH measurements for the pit lake (and groundwater inflows) are in the 7.5-8.5 range. The pH values for pit water suggest that oxidation of sulfide-bearing minerals in the wall rock and associated acid-forming processes by contact with surface and/or groundwater has not significantly influenced water quality as the pit has refilled to its current elevation. Chemical data from the initial refilling period are not available to determine if early pit lake water quality reflected acid-generating conditions. As seen in Appendix F-5, pH values do not exhibit the same degree of stratification in the pit lake water column as other parameters (e.g., temperature and DO).

<u>Nutrients</u>

Phosphorous concentrations were below the detection limit in the analyses of the pit lake water carried out to date at Yerington (Jewell; 2002). Nitrogen concentrations from the Yerington Pit Lake vary, with reported values of 0.08 milligram per liter (mg/L) (Kempton, 1996), 0.67 mg/L (Miller et al., 1996), and up to 5.4 mg/L (Jewell, 1999).

<u>Copper</u>

Copper concentrations of approximately 1 to 64 micrograms per liter (µg/L) are present in most pit lake samples, similar to concentrations observed in the bedrock groundwater monitor wells. The lack of detectable copper in surface waters during the summer and fall in the pit lake may be due to sorption on to precipitating ferric hydroxides, controlled by redox and pH conditions in the epilimnion, and bio-utilization of this element during photosynthesis (e.g., uptake by algae as a trace nutrient). Also, organic matter has a strong affinity for adsorbing copper, as indicated by the correlation between the amount of copper and TOC in lake sediments observed by Sigg et al. (1987). As seen in Appendix F-5, copper exhibits a large degree of stratification in the pit lake water column that is not characteristic of other metals with available depth concentration data.

Selenium

Selenium was detected in all pit lake samples at concentrations that ranged from 89-105 µg/L except for samples collected during January and February 1999, when selenium concentrations were reported to range from 133 to 144 µg/L. The elevated concentrations of selenium as well as iron in the January and February 1999 samples may be due to the dissolution of colloidal ferric iron hydroxides in the acidified, unfiltered samples from this sampling event. Selenium is generally below the detection limit in groundwater samples, suggesting that it is made available to pit lake water by the same geochemical reaction that liberates sulfur, as described in Section 3.3.2. The source of selenium is solid substitution of this element in the sulfide mineralization of the Yerington orebody including pyrite, chalcopyrite, and bornite (Jewell, 1999). As seen in Appendix F-5, selenium concentrations do not appear stratified within the pit lake water column and are also likely controlled by sorption on to precipitating ferric hydroxides.

Other Metals

Several other metals are not typically detected in the pit lake water samples are either: 1) detected at or near the laboratory reporting limit; or 2) detected at anomalous concentrations relative to most other water samples. Metals that are not typically detected, or detected at low concentrations, include arsenic, beryllium, chromium, cobalt, cesium, cadmium, lead, mercury, molybdenum, nickel, titanium, vanadium and zinc. Although thallium is typically not detected, it was reported at elevated concentrations (27 and 43 µg/L) in the 1996 lake samples analyzed by Arimetco (Jewell, 1999). The chemistry of these samples appears inconsistent with most other lake samples and the thallium results may be a result of processes associated with the littoral zone of the pit lake. Antimony was detected at concentrations that range from 7 to 8 µg/L.

Radiochemicals

Uranium was analyzed in samples collected during August 2000 from the pit lake (at depths of 0, 20 and 100 m), the east and west seeps, and the Walker River. Uranium has also been routinely analyzed in the quarterly monitoring samples collected from the bedrock and alluvial monitor wells. Uranium in the pit lake samples ranged from 30 to 32 µg/L. Uranium was detected in the west spring at a concentration of 46 ug/L, and in the east spring at a concentration of 4.5 ug/L. In bedrock wells WW-36 and WW-40, located to the east of the pit, uranium concentrations range from 18 to 22 µg/L. In bedrock well WW-59, located to the northwest of the pit, uranium concentrations range from 27 to 36 µg/L. Concentrations of uranium in alluvial wells B/W-13, B/W-14 and B/W-15 ranged from 3.9 to 5.6, <0.3 to 0.581, and 4.3 to 12 µg/L, respectively. The concentration of uranium in the Walker River during August 2000 was reported to be 5 µg/L. Thorium in the pit lake water samples has never been detected at a concentration above the laboratory reporting limit of 0.2 µg/L.

Depth-Specific Pit Lake Results

Samples from the water column of the Yerington Pit Lake were collected quarterly between May, 1998 and January, 1999. Samples were collected at 10 meter (m) intervals from 0 to 50 m depth and at 15 m intervals below that. A total of 10 samples in the water column were collected. Depth profiles of field parameters measurements and analyte concentrations are provided in Appendix F-5. The following discussion focuses on field parameter measurements (i.e., temperature, DO and pH), major ions and copper and selenium. Other chemicals that are infrequently detected or detected at or near laboratory reporting limits are not discussed below.

Temperature profiles, measured in the deepest part of the lake during February, April, August and November of 2000 indicate that: 1) during the winter, the lake is isothermal and well mixed; 2) during the spring and summer, the lake surface temperature rises causing thermal stratification; 3) in the fall, with cooling of the lake surface, the epilimion increases in thickness until the lake turns over and becomes isothermal (Hershey, 2002).

Dissolved oxygen profiles measured during February, April, August and November of 2000 indicate that: 1) dissolved oxygen is present during all seasons of the year and, thus, the hypolimnion does not become anoxic, which would release reduced metal species from the bottom sediments into the water column; 2) elevated dissolved oxygen in the epilimnion indicates algal respiration; and 3) the pit lake is monomictic.

As mentioned previously, the vast majority of pH measurements for the pit lake are in the 7.5-8.5 range. pH values decrease from approximately 8.5 at the surface of the pit lake to approximately 7.8 at the bottom of the pit lake. The elevated near-surface pH values reflect algal photosynthesis, which likely affect metal solubilities through sorptive processes.

Concentrations of calcium, chloride, magnesium, nitrate, potassium, sodium, silica and sulfate are relatively uniform with depth in the pit lake. Bicarbonate is seasonally variable in the upper 10 m of the pit lake water column with concentrations ranging from approximately 120 to 150 mg/L. Below 10 m, bicarbonate concentrations are uniformly approximately 145 mg/L.

Comparison of Pit Water Data to Water Quality Criteria

Wiemeyer et al. (2004) summarized these comparisons as follows: "For the Yerington Pit Lake, standards for irrigation and watering livestock were not exceeded, with the exception of selenium, which exceeded both standards. Copper concentrations in earlier samples exceeded the acute (i.e., 39 µg/L) and chronic (i.e., 24 µg/L) aquatic life standards; however, samples collected in 2000 and 2001 had concentrations lower than these standards. The single reported molybdenum concentration exceeded the aquatic life standard of 19 µg/L. Total selenium concentrations in water greatly exceeded the acute (i.e., 20 µg/L) and chronic (i.e., 5 µg/L) aquatic life standards. No other elements exceeded the Nevada standards".

Copper and selenium also exceed EPA-promulgated maximum contaminant levels ("MCLs") for drinking water, which are enforced by the State of Nevada under NAC 445A. The MCLs for copper are 1.3 and 1.0 mg/L for primary and secondary standards, respectively, and the MCL for selenium is 0.05 mg/L (primary standard). These comparisons between chemical concentrations and federal and state standards will updated in the Data Summary and Remedial Investigation Reports associated with this Pit Lake RI Work Plan.

3.2.6 Pit Lake Biology

The Yerington Pit Lake is characterized by low nutrient levels, high DO concentrations throughout the lake, and no anoxia. Such conditions generally associated with low biological productivity (Jewell, 1999). Results of biological sampling by Atkins et. al. (1997) showed species dominance by blue-green algae in summer shifting to blue-green algal species dominance in winter and spring, a peak DO in spring in the thermocline associated with the blue-green algae, and low total pelagic-zone biomass in the lake as measured by Chlorophyll a (~ 0.1 µg/L). Zooplankton was limited in abundance and diversity, comprised mainly of rotifers (Atkins et al. 1997). As part of an investigation of five pit lakes in Nevada conducted by the U.S. Fish and Wildlife Service ("USFWS"), Weimeyer et al. (2004) characterized the zooplankton of the Yerington Pit Lake using light traps and plankton nets and found multiple species of cladocerans and copepods. Aquatic insect species were also found, including dragonfly larvae and naucorids.

Hershey (2002) described the introduction of bass into the pit lake to support recreational fishing, although no bass have been recently observed. Diversion of Walker River flood waters in January 1997 provided the potential fish to enter the pit lake. Weimeyer et al. (2004) conducted two days of gillnetting in the Yerington Pit Lake and did not collect any fish during this effort (the mesh size of the gillnet was not described to evaluate any potential bias towards the selection of certain size of fish). Also, given the depth of the pit lake and moderate-to-high oxygenation throughout the lake, deep and shallow refugia may exist for fish to avoid visual and/or gillnetting methods of observation. Consequently, the absence of fish in the USFWS study will be confirmed, as described in Appendix B-1.

Although the Yerington Pit Lake may exhibit low biological productivity, it is an attractor for wildlife including migratory waterfowl. Limited information has been collected to date to characterize the ecology and habitat of, and quantify the flora and fauna within, the Pit Lake OU.

Wiemeyer et al. (2004) collected aquatic vegetation and invertebrate samples from the Yerington Pit Lake, analyzed these samples for trace elements, and compared the results to literature-based dietary effects levels in birds. Several trace metals (most notably selenium and copper) exceeded these benchmarks. As part of the USFWS investigation, a sample of bank swallow eggs was also collected from nests in the pit highwalls, analyzed for trace metals, and the results were found to be below literature-based effects levels for bird eggs.

3.3 Additional Pit Lake Concepts

The information presented below is based on observed conditions at the Yerington Pit Lake, and on physical, chemical and biological processes documented in the literature for other pit lakes located in similar physical environments that are applicable to the Yerington Pit Lake. The conceptual model of the Yerington Pit Lake, graphically presented in Figure 3-1, attempts to incorporate these concepts in a general sense.

3.3.1 Physical Processes

The pit lake water balance provides the basis for accurately predicting future limnological and geochemical conditions and, as such, is the foundation of the conceptual model for the Yerington Pit Lake. The flat portion of the pit lake recovery curve depicted in Figure 3-9 illustrates a future "steady state" condition when the following recharge and discharge elements are in balance (i.e., no annual net gain or loss of pit water volume) over the course of an "average" year:

Recharge Elements

- Direct meteoric precipitation onto the surface of the pit lake;
- Surface runoff from the pit walls, and other areas of the Site, resulting from direct precipitation within the capture area of the pit;
- Highwall seeps, including perched zones; and
- Groundwater inflows through the pit walls at or beneath the water table or potentiometric surface (alluvial or bedrock flow system, respectively).

Discharge Elements

- Evaporative losses from the surface of the pit lake; and
- Outflows into the alluvial or bedrock flow systems.

The hydraulic "steady state" condition is characterized by seasonal fluctuations in pit lake levels around a mean level that does not continue to increase over the long term. Given the climate extremes observed in the area of the Site (i.e., prolonged periods of low precipitation punctuated by 1-2 year droughts and short-duration intense precipitation and runoff events, such as the January 1, 1997 flood), the "steady state" condition may be more accurately defined over a period longer than an "average" year. However, as shown in Figure 3-2, the pit lake appears to respond quickly to extreme events (e.g., the decrease in the slope of the recovery curve after the diversion of flood waters into the pit in January 1997 and subsequent additional inflows of approximately 120 gpm on a continuous basis). Some important recharge concepts include:

- Historical precipitation and other meteorological measurements from the three existing Site meteorological stations can be applied to the pit lake water balance, and re-location of one of the stations to the pit lake edge can provide focused meteorological data.
- Inclusion of all potential runoff from direct precipitation on to the capture area of the pit lake is conservative (particularly with regard to water quality inputs), as the potential for moisture storage in unsaturated alluvial materials is likely to be high and some partitioning of direct precipitation into alluvial storage may be a more realistic concept.
- The volume of direct precipitation and runoff (*Vr*) into the pit lake can be calculated by multiplying the average annual precipitation (*p*) over the area (*A*) of the pit lake and pit walls developed in bedrock, less the volume (*Vs*) of runoff stored as soil moisture according to the equation: $Vr = (A_{\text{bedrock walls+pit lake surface}} \text{ x } p) - Vs$ (assumes runoff evaporated from pit benches is negligible).
- The volume of water flowing through the bedrock into the pit will vary over time as the pit refills. When dewatering operations ended, flow into the pit would not have immediately occurred because of the lag time before rebounding groundwater intersected the pit floor. After a period of rapid groundwater inflow over the initial refilling period, the inflow will approach a "steady-state" condition as the pit water hydraulically equilibrates with the surrounding groundwater, the ambient precipitation, and evaporation (e.g., as depicted in Figures 3-1 and 3-8).
- Groundwater inflow rates included in the pit lake water balance can be determined using analytical solutions or numerical models that incorporate all water balance components.

Some important Site-specific discharge concepts include:

- The volume of net evaporation V_{ne} can be calculated by multiplying the net evaporation rate R_{ne} by the surface area A_{lake} of the pit lake: $V_{ne} = R_{ne} \text{ x } A_{lake}$.

- Pit water outflow into the alluvial aquifer from the western pit margin will be developed using hydraulic properties of the aquifer and monitor well data. As with inflow (i.e., refilling rate) estimates, discharge rates can be determined using analytical solutions or numerical models that incorporate all water balance components.
- Pit water outflow into the bedrock flow system during potential seasonal discharge events will be estimated using hydraulic properties of the bedrock and monitor well data, as part of the overall pit water balance analysis.

Once the "steady state" pit lake water balance is established, limnological effects can be superimposed on the hydrology of the pit lake as the next step in the development of the conceptual model. This approach to phased conceptual model development leads to the influence of limnological process on pit lake geochemistry.

Limnological Processes

Lyons et. al. (1994) noted that pit lakes are different than most natural lakes and man-made reservoirs because pit lakes generally have: 1) smaller surface areas and greater depths; and 2) no shoreline or shallow water area, limiting development of biological communities in the littoral zone. Limnological processes that will most influence water quality in the Yerington Pit Lake are hydrodynamic mixing and biological productivity (Atkins et. al., 1997). Hydrodynamic mixing is influenced by wind speed and direction relative to the geometry of the pit water surface and water density, which is a function of thermal and chemical gradients in the pit water column. Light intensity, nutrient availability and the type of plankton present in the water column will affect the biological productivity of the pit lake. Hydrodynamic and biological processes affect pH and the distribution of oxygen in the water column that, in turn, will influence the chemical character of the pit lake (e.g., chemical data provided in Appendix F and Jewell, 1999).

During the summer months, the pit lake surface may adsorb heat more rapidly than mixing can redistribute the heat (Wetzel, 1983). For some lakes, this process leads to summer stratification, in which three distinct zones exist within the water column (Geomega, 2003). The surface layer (i.e., the epilimnion) is a warmer, well-mixed layer that does not mix with the colder, undisturbed, lower layer (i.e., the hypolimnion). The zone between these layers (i.e., the metalimnion) is characterized by a steep thermal gradient (i.e., the thermocline). In the fall, turnover of the water layers occurs when the warm water of the epilimnion cools, sinks and mixes with the deep, colder water of the metalimnion and hypolimnion. When a lake turns over, the entire water column is mixed and chemicals are homogeneously distributed throughout the water column (Wetzel 1983).

Temperature stratification can also result in chemical stratification Wetzel (1983), as a result of an induced density gradient, which is characterized by a deeper portion of the lake (i.e., monimolimnion) that is isoloated form the overlying, well-mixed surface layer (i.e., the mixolimnion). These two zones are separated by a steep chemical gradient (i.e., the chemocline) in static lakes, generally due to depleted oxygen concentrations. Several mechanisms can result in a chemically stratified lake where the two zones are perennially isolated (e.g., inflows that introduce saline water into the hypolimnion, accumulation of salts in the hypolimnion due to sediment decay, meteorologic conditions).

Lake stratification may lead to reduced DO concentrations in the hypolmnion because oxygen is supplied to lakes from the atmosphere, photosynthesis, and physical mixing within the lake (Wetzel, 1983). In addition, oxygen is consumed during respiration and the oxidation of organic matter. Re-oxygenation of the water column during turnover of the pit lake will also influence the physical characteristics and chemical stratification profile due to the formation of mineral phases (i.e., amorphous ferric hydroxide). Such precipitates may settle out of the water column to form lake sediments that can sequester other dissolved metals (e.g., arsenic, copper, selenium and zinc). In summary, oxygen distribution is dynamic and depends a number of factors including inputs from the atmosphere, photosynthesis, hydrodynamic mixing, and depletion from chemical and biotic oxidation (Wetzel 1983).

Evaporation of the pit lake surface is a physical process that can also influence pit water quality in the epilimnion beneath the pit lake/atmosphere interface. Evaporation will: 1) increase the concentrations of some chemicals (e.g., TDS and salinity), as water evaporates and the pH becomes more alkaline (Eugster and Hardie, 1970); and 2) decrease the concentrations of other chemicals (e.g., calcium, due to precipitation of calcite). In general, evaporation increases the concentrations of dissolved solutes, and can facilitate the precipitation of iron hydroxides and calcite by increasing the concentration of Fe^{3+} and Ca^{2+}. For example, calcite precipitation will occur according to the following reaction: $Ca^{2+} + 2HCO_3^- = CaCO_{3\,(s)} + CO_{2\,(g)} + H_2O$ (Langmuir 1997). Higher temperatures at the pit lake/atmosphere interface will reduce the solubility of calcite and CO_2 (Langmuir 1997), and the subsequent flux of CO_2 from the lake to the atmosphere as calcite precipitates has the effect of further driving the formation of calcite. Loss of CO_2 also increases the pit lake pH, further facilitating calcite precipitation.

Similar mechanisms operate to facilitate the precipitation of other solid phases (e.g., amorphous ferric hydroxides), which may form sediments as they settle in the water column. Note that some precipitates may be too fine to settle, and would remain as a reservoir of sorbing media in the water column. Precipitation and settling of mineral phases resulting from the physical processes and chemical reactions described above, and the settling of wind blown dust that falls on the pit lake surface, can result in the accumulation of sediments on the pit lake bottom and on flat-lying pit benches below the lake surface. The accumulation of sediments can locally modify the hydraulic characteristics of the pit lake by reducing groundwater inflow and outflow rates.

In addition to the limnological processes described above, the physical mixing of bedrock inflows, incident precipitation, surface water derived from pit area runoff, and highwall seeps will influence pit lake water quality. The relative contributions of these sources to the pit lake, at present and in the future, will be evaluated in the water balance calculation. As the pit lake continues to refill, its surface area will continue to expand and the physical and chemical effects of evaporation described above will increase over time. This condition appears to be supported by the pit lake hydrograph presented in Figure 3-2.

3.3.2 Geochemical Processes

The primary source of recharge into the Yerington Pit Lake is conceptualized to be bedrock groundwater recovering from pit dewatering operations, resulting in pit lake chemical characteristics that, in general, reflect the water quality of the bedrock flow system. In addition, it is conceptualized (e.g., Gill, 1951) that the dominant source of recharge into the bedrock aquifer in the area of the pit is the Walker River. The similarity of water quality characteristics between the bedrock and alluvial wells on the east side of the pit, which are proximal to the Walker River, Walker River water and pit lake water is evidenced by the water quality data and graphs provided in Appendix F of this Pit Lake RI Work Plan. Bedrock water quality, considered to be a starting point for the characterization of pit lake geochemistry, will be modified by: 1) the physical processes described above; 2) the oxidation of sulfide-bearing minerals in the pit walls and associated chemical reactions; and 3) the physical and chemical interaction of the wall rock with groundwater inflows and pit lake water through adsorption, and potential mineral dissolution, precipitation, etc.

These physical and chemical processes may be addressed in a preliminary way by comparing the behavior of conservative and reactive constituents over time such as chloride and iron, respectively. This approach can provide an initial assessment and differentiation of the effects of evaporation, wall rock chemical reactions, and other limnological and biological processes on pit water quality. Ratios between chloride in the lake water and the inflowing groundwater can be compared to other chemicals using the following equation to assign enrichment or depletion factors for those chemicals (Geomega, 2003):

$$\text{ion}^* = \text{ion}_{gw} \text{ x } (\text{Cl}_{lake}/\text{Cl}_{gw}).$$

For example, an increase in dissolved sulfate in pit lake water relative to groundwater is likely the result of oxidation of sulfide minerals (e.g., pyrite and copper-bearing sulfides) in the pit walls and the flushing of the oxidation products into the pit lake. This concept can be seen with the following chemical equation that partially describes the oxidation of pyrite and the creation of sulfate and acid:

$$FeS_2 + 7H_2O + 2O_2 = Fe(OH)_3 + 2SO_4^{2-} + 11H^+$$

In addition to the oxidation of sulfides as a method of increasing sulfate concentrations in the pit lake, evapoconcentration effects in the epilimnion can also increase sulfate concentrations. As described above for pit lakes in arid regions, the water quality of the Yerington Pit Lake is anticipated to be affected by evaporative water lossess and subsequent seasonal solute evapoconcentration in the epilimnion (e.g., Miller et al. 1996). Evapoconcentration effects will be distributed throughout the water column during lake turnover events. This concept can be used, along with evaporation measuements, to provide a geochemical check on the water balance calculation for the pit lake. The following additional pit lake concepts are useful for understanding current pit lake water quality and projecting future water quality under "steady state" conditions.

<u>Equilibrium Phases – Gases</u>

Equilibrium phases include either gases or solids, which can reversibly react with the pit lake water. Equilibration between the atmosphere and dissolved gases in the filling lake will be limited by the effectiveness of diffusive transport and by pit lake hydrodynamics (i.e., seasonal turnover). Deeper parts of the pit lake that are not in contact with the atmosphere will likely exhibit non-equilibrium partial pressures of dissolved gases (e.g., carbon dioxide). The geochemical effects of carbon dioxide and oxygen, which are ubiquitous in groundwater, lakes and the atmosphere, are discussed below.

Carbon Dioxide

Within the pit lake, carbon dioxide (CO_2) may be produced by microbial degradation of organic matter or the precipitation of calcite. Changes in the partial pressure of CO_2 (Pco_2) within the water column due to physical, chemical and biological processes will, in turn, affect pit lake geochemical conditions. Based on observations summarized by Geomega (2003) for other Nevada pit lakes, pit lake waters exhibit a range of average Pco_2 values from $10^{-3.0}$ to $10^{-2.1}$ atmospheres. Therefore, the average Pco_2 in the pit will trend from the influent water partial pressure (atm.) to approximately $10^{-3.0}$ atm. as the pit lake matures.

Dissolved Oxygen and Redox Potential

The oxidation-reduction (redox) potential (i.e., the pe or Eh) of the pit lake is an important variable because many soluble elements in a pit lake can exist in multiple oxidation states (e.g., Fe^{2+}/Fe^{3+}). The redox state of an element will determine its chemical and biological behavior, including the toxicity of the element (e.g., selenium) and its solubility (e.g., iron). Redox potential can also control the stability of ferric hydroxides as a solid phase. Redox-sensitive elements in the Yerington Pit Lake include iron, copper and selenium.

The redox state of the pit lake can be determined either by direct field measurements or by indirect methods using the ratios of dissolved redox-sensitive species (e.g., Fe^{2+}/Fe^{3+}). In the pit lake, oxygen is conceptualized to have significant oxidizing potential because the atmosphere provides an unlimited source of oxygen to surface waters (Langmuir 1997). Similarly, if bedrock groundwater inflows into the pit are ultimately sourced from the Walker River, this recharge source can contribute dissolved oxygen to the water column.

<u>Equilibrium Phases – Solids</u>

As the pit lake refills, water will contact the pit walls, and chemical equilibrium between minerals in the pit walls and solutes (metals and anions) in the lake will be driven by solute exchange. Such processes include the dissolution of minerals in the pit walls (i.e., solute loading) or by precipitation of supersaturated solids from the water column (i.e., solute removal), and subsequent accumulation of sediments on flat portions of the pit (e.g., the lake bottom or interim benches). A common process is the precipitation and dissolution of amorphous ferric hydroxides (AFH) in the pit water column (Geomega, 2003).

Amorphous Ferric Hydroxide

AFH is a ubiquitous, stable, iron-bearing solid that readily forms as the result of the oxidation of ferrous (Fe^{2+}) iron according to the following reactions:

$$Fe^{2+} + \frac{1}{4} O_2 + H^+ \rightarrow Fe^{3+} + 1/2\ H_2O\text{; and}$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 \downarrow + 3H^+$$

The precipitation of AFH sequesters metals as cations (e.g., $A1^{3+}$, Cu^{2+}, Zn^{2+}) and anions (e.g., SO_4^{2}, SeO_4^{3-}, AsO_4^{3-}) from solution by co-precipitation and adsorption processes (Geomega, 2003). Sorption of metals and anions to AFH is a function of pit lake pH (Davis and Eary, 1997). The removal of solutes by the precipitation of AFH is an important process controlling the solubility of many metals (Drever, 1988). Precipitation and settling of AFH through the water column can sequester solutes from solution, resulting in metal-bearing sediments at the bottom of the pit lake (e.g., Miller et. al., 1996; Davis and Eary, 1997).

Calcite and Gypsum

Calcite and gypsum are additional solid equilibrium phases that may influence the geochemistry of the Yerington Pit Lake. The supersaturation of these phases in the epilimnion may result from evaporation, the deposition of atmospheric dust, and/or an increase in near-surface pH values due to photosythesis during the summer months. For example, Geomega (2003) estimated that up to 485 kilograms/year of additional $CaCO_3$ could be added to Nevada pit lakes. Two possible calcite reactions may occur during the chemical evolution of the Yerington Pit Lake: 1) calcite dissolution during initial refilling time when influent wall rock leachate contains acidity; and 2) calcite precipitation during the mature phase of the lake when pit water is equilibrating with atmospheric carbon dioxide. Dissolution of calcite by acidic leachate according to the reaction: $CaCO_3 + H+ \rightarrow HCO_3^- + Ca^{2+}$ serves to maintain neutral pH conditions and increase calcium concentrations in the water column. Precipitation of calcite could also represent an important geochemical control on pit water quality by incorporating and removing metals from solution (Geomega, 2003).

3.3.3 Biological Processes

As noted above, pit lake water quality will be influenced by the following biological processes: 1) consumption of oxygen during respiration and the oxidation of organic matter; 2) the production of carbon dioxide by microbial degradation of organic matter; and 3) uptake of trace elements by primary producers. Given the limited biological information available for the

Yerington Pit Lake OU, the existing conceptual model for OU-specific biological effects on pit water quality is correspondingly limited. The proposed ecological investigations and SLERA Work Plan, provided in Appendix B of this Pit Lake RI Work Plan, will significantly improve the conceptual model of the pit lake with respect to biological processes.

3.3.4 Evolutionary Pathway from Present to Future "Steady State" Conditions

Nearly 20 years after open pit mining operations ceased, the Yerington Pit is still in the process of refilling, and the question of how the pit lake will evolve is conceptualized in this section. The physical, chemical and biological processes described above will interact to create the future "steady state" condition. Based on the pit lake recovery curve presented in Figure 3-11, the "steady state" condition is projected to occur by 2020. Once the lake elevation equilibrates with that of the bedrock and, potentially, the alluvial groundwater flow systems, the lake will reach a "steady state" condition on an average annual basis. Seasonal and longer term variability in lake level, hydrodynamics and water quality would be expected as a result of climate effects on the pit water balance. Additionally, significant changes in the pit highwalls resulting from erosion and unanticipated events (e.g. a large magnitude earthquake focused in the immediate area of the Site, or a repeat of the January 1997 flood event on the Walker River) could potentially affect the water balance and/or pit lake water quality for a limited period of time.

Based on the information presented in the preceding sections of this Pit Lake RI Work Plan, the following key conceptual model elements are important to assessing future pit lake conditions:

- Historic Site-specific and regional meteorological conditions indicate a high degree of seasonal and annual variability. Relevant meteorological data will need to be integrated into an annual or longer term assessment of "average" conditions for the pit lake water balance.
- Groundwater flow from the surrounding bedrock into the pit is likely recharged predominantly by the Walker River, indirectly through alluvial materials (distal alluvial fan, transitional and fluvial depositional facies). Bedrock recharge from the Singatse Range is conceptualized to be relatively minor, or insignificant, in comparison.
- The current pit lake hydrograph indicates a flattening of the recovery curve, which is consistent with other pit lakes, particularly those in an arid or semi-arid environment where the evaporation rate exceeds the precipitation and recharge rate. Flattening of the

recovery curve can be attributed to: 1) the increase in pit lake surface area, and resulting increase in evaporation losses; and 2) the interception of the pit lake surface with the bedrock-alluvial contact at the west margin of the pit, and potential outflow into the alluvial aquifer at that location.

- Highwall seep discharges into the pit lake will continue to play a minor role in the pit lake water balance and, potentially in the evolution of pit water quality. Given that the east highwall seeps are directly sourced from the Walker River and appear to have similar water quality characteristics as the bedrock and alluvial wells on the east site of the Site, geochemical effects from this source are not expected to be significant. The minor flow contributions from the west seeps are also not expected to significantly affect pit water quality. Both sources have the potential to continue to load minor amounts of nutrients to the pit lake. Other highwall seeps and surface water runoff into the pit will also have relatively insignificant effects on pit water quality.
- The five-year hiatus of pit lake water quality data since 2002 indicates the need for additional geochemical characterization. With the exception of higher sulfate and metals concentrations in the lake water compared to bedrock source and Walker River water, the overall similarity of these waters indicates that significant changes in future pit lake water quality would not likely occur. The major loading of sulfate and metals into the pit lake is conceptualized to have occurred during the earlier stages of refilling when the pit lake level was below the base of the oxidized portion of the orebody, as evidenced by the continued decrease in copper concentrations in the pit lake through 2002.
- Pit wall failures have the potential to affect pit lake water quality on a short-term basis by introducing large volumes of alluvial and bedrock materials into the water column. Given that the bedrock highwalls above the pit lake surface are composed of oxidized porphyry materials, the introduction of such materials into the lake should not create acidic conditions or release significant amounts of metals.
- Evapoconcentration will play a more dominant role in pit lake geochemical processes as the lake level continues to rise. Evaporation will likely cause more precipitation of solids in the epilimnion, consistent with the geochemical process descriptions provided above. Other relatively minor geochemical effects may be created by the increased volume of the pit lake at "steady state" that could affect existing hydrodynamic conditions, and related limnological and biological processes.
- The volume of stored water in the existing and future Yerington Pit Lake has some economic value, and the water rights to that volume are owned by a private individual and Lyon County. The industrial, commercial and/or other beneficial use of that water could affect the pit lake water balance and water quality. In addition, the potential future use of the pit as a flood management component, and diversion of Walker River flood waters into the pit, may also affect the pit lake water balance and water quality.
- The preliminary human health and ecological risk aspects of the conceptual model for the Yerington Pit Lake are presented in the HHRA and SLERA Work Plans (Appendices A and B, respectively, of this Pit Lake RI Work Plan).

Jewell (1999) concluded that: 1) the Yerington pit lake will not become anoxic, either in its short term (terminal phase) or in the long term, once the flow through stage has been achieved; 2) anoxic waters with associated high concentrations of metals will probably not be a factor in the overall environmental impact of the pit lake; 3) the TDS concentration of groundwater entering the Yerington pit lake is relatively low, even though evaporation has increased the total solutes in the lake by 50 to 100 percent since mine closure; and 4) the TDS concentration of the lake remains low, and water quality in the Yerington Pit Lake is good, with only a small number of chemicals (e.g., copper, sulfate and selenium) present at concentrations greater than a 50 percent higher concentration level observed for bedrock groundwater.

Geomega (2003) concluded for the Getchell Mine pit lakes that: 1) the ability to make long term predictions of water quality in pit lakes involves an extremely large number of meteorological, hydrological and geochemical factors; 2) the most important aspect of the long term behavior of pit lake waters is the tendency of pit lake waters to develop a permanently stratified water column, which will subsequently become anoxic, thereby significantly affecting pit lake chemistry; 3) the chemogenetic pathway for pit lakes is controlled by the chemistry of the recharging groundwater, which eventually overwhelms the leachate chemistry of the wall rock; and 4) as the pit lake matures, evapoconcentration will increase solute concentrations in the epilimnion, which will cause adsorption onto precipitating phases. These concepts appear relevant for the Yerington Pit Lake.

Jewell (1999) noted that "the long term stability, redox conditions, and geochemistry of the water column in the Yerington Pit Lake should be evaluated within the context of climate extremes expected over the next century", including the potential effects of atmospheric warming. Jewell investigated two climate extremes based on global climate model ("GCM") results (Houghton, 1990; Figures 5.4-5.6), which might increase stratification during the next 50 years: 1) mean temperature was assumed to increase by 6^{o}C; and 2) annual precipitation was increased by 2 mm/day (0.73 m/year). Jewell (1999) concluded that, for all modeled scenarios for existing conditions and for increasing temperature and precipitation conditions, the Yerington Pit Lake would overturn on an annual basis.

Jewell (1999) also concluded that permanent stratification and the associated occurrence of any long term anoxia in the Yerington Pit Lake would not occur due to: 1) the relatively low total dissolved solids of the water column; and 2) the relatively small amount of surface water which enters the lake on an annual basis; and 3) the lack of any driving force to develop a vertical density gradient (e.g., significant volumes of surface water inflows). Under existing conditions, Kempton (1996, Figure 1-3) noted that evaporation losses during the summer months results in higher TDS concentrations in the epilimnion than in the hypolimnion during this seasonal period of thermal stratification. Based on these conclusions regarding existing and potential future hydrodynamic conditions, which preclude the development of a vertical density gradient, the hydrodynamics of the pit lake under "steady state" conditions are not anticipated to affect the geochemical evolution of the pit water.

The concepts presented above support the DQO statements presented in Section 4.0. Testing of the key concepts will be performed pursuant to the FSAP presented in Section 5.0 of this Pit Lake RI Work Plan. In addition, biological concepts will be addressed by the proposed ecological investigations associated with the SLERA Work Plan (Appendix B).

SECTION 4.0
DATA QUALITY OBJECTIVES

The DQOs described in this Pit Lake RI Work Plan have been developed to ensure that reliable data are acquired for decision making by the project management team described in Section 2. A systematic seven-step planning approach, described in *Guidance on Systematic Planning Using the Data Quality Objective Process* (EPA 2006a), will establish performance or acceptance criteria and provide the basis for designing the FSAP described in Section 4.0. The DQO process consists of the following seven iterative steps:

- Step 1: State the Problem
- Step 2: Identify Study Goals
- Step 3: Identify Information Inputs
- Step 4: Define the Boundaries of the Study
- Step 5: Develop an Analytical Approach
- Step 6: Specify Performance or Acceptance Criteria
- Step 7: Develop the Plan for Obtaining the Data.

The following generalized problem statement for the pit lake, presented as DQO #1 in Table 4-1, provides the basis for additional DQOs: "Existing physical, chemical and biological characteristics of the pit lake and surrounding pit wall environment are not completely known, and future pit lake conditions are uncertain. Pit lake water levels continue to rise towards the pre-mining bedrock groundwater elevation, and will eventually reach a "steady-state" water balance condition where recharge rates (e.g., groundwater inflows, Walker River seepage and precipitation) will equal discharge rates (e.g., evaporation and groundwater outflows) on an average annual, or longer period, basis. Existing and future pit wall stability conditions are unknown. The distribution of chemicals at various lake depths, including seasonal variations, is known for a limited depth range and time period, but the full extent of current and anticipated future water quality conditions is not known. Proposed pit lake water balance, slope stability, limnological, geochemical and biological investigations will support a projection of future pit lake conditions, and will address potential human health and ecological risk issues associated with the Yerington Pit and Pit Lake." Based on this general problem statement and the SOW elements presented in Section 1.0, the following objectives for the field investigations described in Section 5.0 of this Pit Lake RI Work Plan have been identified:

- Determine if existing pit lake conditions can be used to predict "steady state" conditions based on field investigations, monitoring programs, laboratory analysis of collected data and interpretation of the data.
- Establish the hydrologic relationships between the pit lake and surrounding alluvial and bedrock groundwater flow systems to support the characterization of existing water balance conditions.
- Determine the existing water balance condition to predict the "steady state" water balance condition of the pit lake using measured and calculated inputs.
- Establish existing pit lake limnology characteristics to predict "steady state" hydrodynamic conditions and potential effects on pit lake water quality.
- Characterize the physical, chemical and biological properties of pit lake sediments, and potential sediment influence on water quality and biota.
- Characterize the pit lake biological productivity and nutrient pathways, and their potential effect on pit water quality.
- Predict future water quality characteristics of the pit lake based on the integration of previous DQOs.
- Assess the nature and composition of aquatic plant and animal species, and their potential uptake by higher semi-aquatic vertebrates.
- Characterize the habitat associated with riparian and upland sections of the pit lake shore and proximal highwall areas.
- Assess potential ecological risk associated with the existing and future "steady state" pit lake.
- Assess potential human health risk, including tribal lifeways, associated with the existing and future "steady state" pit lake.
- Update the previous analysis of highwall stability of the existing and future pit, and potential geotechnical effects on the hydrodynamic or chemical aspects of the existing and future "steady state" pit lake and the health and safety aspects of performing characterization and monitoring activities in and around the lake.

Each of these objectives, and associated steps towards obtaining the appropriate data, are summarized in Table 4-1.

Table 4-1. Data Quality Objective Steps

DQO	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
	Problem Statement	**Identify Study Goals**	**Identify Information Inputs**	**Study Boundaries**	**Develop The Analytical Approach**	**Specify Performance or Acceptance Criteria**	**Develop the Plan For Obtaining Data**
DQO #1 – General Problem Statement	Existing physical, chemical and biological characteristics of the pit lake and pit environment are not completely known, and future pit lake conditions are uncertain. Pit lake water levels continue to rise towards the pre-mining bedrock groundwater elevation, and will eventually reach a "steady-state" water balance condition where average annual recharge rates (e.g., groundwater inflows, Walker River seepage and precipitation) will equal discharge rates (e.g., evaporation and groundwater outflows). Existing and future pit wall stability conditions are unknown. The distribution of chemicals at various lake depths, including seasonal variations, is known for a limited depth range and time period, but the full extent of current and anticipated future water quality conditions is not known. Proposed pit lake water balance, slope stability, limnological, geochemical and biological investigations will support a projection of future pit lake conditions and address potential human health and ecological risk issues.	Determine if current or short-term future pit lake water quality conditions, to be quantified during proposed site investigations and subsequent monitoring, are representative of conditions that will be observed when the pit lake reaches the hydraulic "steady-state" condition. The hydraulic definition of "steady-state", as defined in Section 3.0 of this Pit Lake RI Work Plan, will be evaluated in terms of its applicability to potential future steady state limnological and geochemical conditions in the pit lake.	Information inputs include water level measurements, seasonal and depth-specific limnologic and pit water chemical data from previous and planned monitoring events and investigations. Specific inputs are described in subsequent DQOs.	The spatial study boundary includes the three-dimensional extent of the Yerington Pit Lake and surrounding areas that contribute inflows from the alluvial and bedrock groundwater flow systems, to be determined. The spatial boundary includes the perimeter of the open pit where slope stability information may be gathered. The spatial boundary also includes potential future up-gradient and down-gradient portions of the bedrock groundwater flow system. The recharge sources to the pit lake and its hydraulic capture area in the bedrock and alluvial flow systems, to be determined, will ultimately define the spatial boundary. The vertical extent of the study area will be from the pit lake surface (epilimnion) to the base of the water column (hypolimnion), and from the portion of the highwalls exposed above the pit lake surface to the pit rim. The highwall vertical extent includes areas where ephemeral or perennial seeps provide inflows into the pit, and where slope stability information may be obtained. The vertical extent will also include the depth range from the ground surface to the alluvial water table and to the potentiometric surface in the bedrock flow system. The temporal extent of the study boundary encompasses seasonal, annual or other variability in pit lake levels, pit water quality, highwall seep water quality, and groundwater quality in the alluvial and bedrock flow systems. The temporal extent of the study boundary also encompasses seasonal variability in terrestrial or avian wildlife use of the pit lake, and potential food web development. Although the temporal extent of pit lake monitoring cannot be defined at present, it will be based on the ability to predict future "steady-state" conditions from observed conditions (estimated 5-year time frame to implement this pit lake RI Work Plan and conduct sufficient monitoring).	The analytical approach includes the following activities: ▪ Review and assess existing data including pit geology, previous limnologic and water quality studies and groundwater conditions in the area of the pit lake. ▪ Identify data gaps and inputs required to establish the pit lake water balance under existing and future "steady-state" conditions, including the extent of the existing capture zone in the bedrock groundwater flow system surrounding the pit lake. ▪ Identify data gaps and inputs required to define existing pit lake water quality and limnological conditions including seasonal and depth-specific water quality variability. ▪ Compare new data developed under this Pit Lake RI Work Plan with existing data to assess the physical, chemical and biological evolution of the pit lake. ▪ Develop monitoring activities to observe seasonal and temporal pit lake and groundwater quality trends and the pit lake water balance to predict "steady-state" conditions. ▪ Input physical and chemical data into appropriate hydraulic, chemical and biological models/calculations to accurately predict future pit lake conditions and the potential for human health and ecological risk.	Information obtained from historic data and data collected from the implementation of this Pit Lake RI Work Plan will be used to determine if adequate data have been obtained to predict future "steady-state" pit lake conditions. The adequacy of the data will depend on factors such as seasonal and temporal variability, and variability with depth-specific water quality data. For example, if the analysis of chemical concentrations at various depths in the water column during the four seasons demonstrates that existing data and data developed as part of this Pit Lake RI Work Plan are statistically similar, pit lake monitoring may be used to predict "steady-state" conditions.	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities to be determined. Phasing of data collection and interpretation is proposed as follows: ▪ FSAP implementation and detailed monitoring to be performed to collect two full years of detailed monitoring data. ▪ Subsequent, reduced monitoring of key input parameters for up to three years to be able to predict "steady state" pit lake water quality conditions, which may pose a risk to human health or the environment, and the potential for the lake to become a flow-through system. ▪ One year to compile and integrate all appropriate data, construct and calibrate numerical models and perform necessary calculations to accurately predict future pit lake conditions and the potential for human health and ecological risk.

Table 4-1. Data Quality Objective Steps

DQO	Step 1 Problem Statement	Step 2 Identify Study Goals	Step 3 Identify Information Inputs	Step 4 Study Boundaries	Step 5 Develop The Analytical Approach	Step 6 Specify Performance or Acceptance Criteria	Step 7 Develop the Plan For Obtaining Data
DQO #2 – Hydraulic Relationship Between Pit Lake and Bedrock and Alluvial Flow Systems	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. The existing hydrologic relationship between the bedrock and alluvial groundwater flow systems and the pit lake is not well understood. Groundwater elevation and pit lake level monitoring data can be integrated to define the current "cone-of-depression" around the pit lake and the long-term pit lake water balance under current and "steady-state" conditions including the potential for the pit lake to become a flow-through system.	Establish the hydrogeologic relationships between the pit lake and surrounding bedrock and alluvial groundwater flow systems. Related objectives include the potential for a groundwater divide between the pit lake and the Process Areas, outflow from the pit lake into the alluvium on the west side of the pit, and a gradient-reversal condition as the pit lake reaches hydraulic "steady-state" conditions.	Groundwater elevation data from alluvial and bedrock flow systems to be obtained from up-gradient, down-gradient and cross-gradient locations around the pit lake. Pit lake level data. Other information inputs described below in DQO #3 (e.g., rainfall, runoff, and spring and seep data) will augment these inputs for the overall pit lake water balance.	The study area boundary, as previously described in DQO #1, is applicable without modification to this DQO. The study area boundary may extend beyond the location of the monitor wells initially proposed in the FSAP based on the assessment of hydrogeologic conditions in the bedrock groundwater flow system.	Compare groundwater elevation data with pit lake water level data to evaluate groundwater flow directions. Use water quality data to confirm the hydrologic relationships determined from the comparison of groundwater elevation data with pit lake water level data. Statistically validate the data sets and identify any limnological or groundwater recharge events that may affect pit lake levels. After completion of FSAP and subsequent groundwater monitoring activities for up to three years after FSAP completion, and the activities described in DQO #3, predict hydraulic "steady-state" conditions using analytical techniques.	Statistical validation of data sets from ongoing monitoring of surrounding groundwater elevations and pit lake levels over time.	Data and information to support this DQO include both historic data and new groundwater elevation and pit lake water level data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities to be determined. Data will be collected from seven bedrock and two alluvial groundwater monitor wells.
DQO #3 – Pit Lake Water Balance	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. The existing pit lake water balance is not well understood, and the ability to accurately predict the long-term "steady state" water balance based on the characterization of existing conditions, subsequent monitoring and analysis is uncertain.	Establish existing and long-term pit lake water balance conditions including estimates and measurements of direct precipitation, surface water runoff, groundwater inflows and surface water inflows, evaporation and related climate data, and limnological data.	In addition to the inputs identified in DQO # 2 (i.e., pit lake level and groundwater elevation data), the following inputs will be required: ▪ Seasonal/annual estimates of pit area runoff flows into the lake, including flows via infiltration of meteroric water into bedrock. ▪ Seasonal/annual measurements of direct precipitation onto the lake. ▪ Seasonal/annual measurements or estimates of flows from pit highwall seeps into the lake. ▪ Seasonal/annual estimates of evaporation from the pit lake surface, including the effects of wind shear. ▪ Inputs from pertinent limnologic studies described in DQO #4 (e.g., pit lake surface temperature data). Obtain the necessary variables to compute P-E values: wind speed, relative humidity, surface air temperature, and surface water temperature (DQO #4).	The study area boundary, as previously described in DQO #1, is applicable without modification to this DQO.	Estimate the amount of surface water runoff that is captured by the pit area and partitioned into direct surface water runoff into the lake, that is infiltrated into bedrock on pit benches and that pooled on pit benches and evaporated. Compute evaporation using standard Bowen ratios and other methods (e.g., Shuttleworth, 1993). Integrate these calculations with groundwater elevation and pit lake level data (DQO #2), precipitation data, the seep flow data and the evaporation estimates into a seasonal and annual water budget for the pit lake. Incorporate these data into an analytical model of the pit lake water balance after three years of monitoring and data collection subsequent to the completion of FSAP activities.	Calibration of analytical methods to match observed conditions. The sensitivity of water balance input parameter values will be developed during the calibration process. Work with EPA hydrogeologists to establish input parameter sensitivity and calibration success criteria.	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities including: ▪ Continue use of at least one existing meteorological station at the site to measure air temperature, wind speed, and relative humidity on an hourly basis, and daily precipitation (see DQO #4). ▪ Re-locate an existing meteorological station to an area closer to the pit lake to collect more focused data. ▪ Monthly measurements of seep and spring data from highwall sources for two years, followed by up to three years of quarterly monitoring. ▪ Calculations, by difference, of pit lake runoff and bedrock infiltration inflows.

Table 4-1. Data Quality Objective Steps

DQO	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
	Problem Statement	**Identify Study Goals**	**Identify Information Inputs**	**Study Boundaries**	**Develop The Analytical Approach**	**Specify Performance or Acceptance Criteria**	**Develop the Plan For Obtaining Data**
DQO #4 – Pit Lake Limnological Conditions	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. Existing limnological conditions in the pit lake are not completely known, and the ability to accurately predict long-term "steady state" limnological conditions based on existing conditions and subsequent monitoring is uncertain.	Evaluate pit lake seasonal turnover and stratification periods, including the timing of these conditions, and how these conditions affect water quality along the vertical water column of the pit lake.	Measurements of vertical and seasonal chemical, temperature, dissolved oxygen, and specific conductivity values in the pit lake water column. Continuous measurement of surface water temperature.	The study area boundary, as previously described in DQO #1, is applicable without modification to this DQO.	Standard analytical methods employing the Wedderburn number (a dimensionless number dependent on the vertical density gradient, wind velocity, lake width, and thermocline depth; e.g., Kalff, 2002) will be used to integrate the collected data and determine controls of the seasonal and long- term stability of the pit lake water column. Biological oxygen demand (BOD) in the lake hypolimnion will be determined using standard analytic methods. As appropriate, in concert with EPA, assess the need to develop a hydrodynamic model of the pit lake (e.g., CE-QUAL-W2) to simulate the following parameters: water surface elevations, horizontal and vertical velocities of water masses, energy budget variable density, temperatures, precipitation, tributary and groundwater inflows, evaporation, algae, chemical concentrations and dissolved oxygen.	Calibrate analytical and numerical models to evaluate the water budget including controls of water column stratification (seasonal or permanent basis), hypolimnotic oxygen demand, inflows from surface water and groundwater, and outflows due to evaporation.	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities including: ▪ Compilation of all previous temperature and specific conductivity measurements, and chemical data, from the pit lake water column. ▪ Monitoring of temperature, conductivity, and dissolved oxygen in the water column using a standard multi-sensor water probe on a monthly basis. ▪ Collection of pit lake surface temperature data at one-hour intervals using a self-recording thermistor installed up to three feet below the pit lake surface. ▪ Collection of water quality samples from specific depths within the pit lake water column and analysis of the samples for metals, radiochemicals and other parameters analyzed from groundwater monitoring wells.
DQO #5 – Pit Lake Sediment Characteristics	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. Pit lake sediment characteristics are unknown, and it is uncertain how these sediments can influence the pit lake water balance by affecting groundwater inflows and pit water outflows, and lake water chemistry by the adsorption and desorption of reactive chemicals and through chemical diagenesis immediately below the sediment-water interface. If sediment accumulations are found to be thick enough to sample, determine possible geochemical effects of lake sediments on pit lake water quality.	Characterize the physical and chemical conditions of pit lake sediments and potential influence on pit lake water quality and effect on pit lake biota. Assess, if practicable, any differences between shallow and deep sediments, as deep sediments may not be accessible from the pit lake surface. An assessment of the importance of the deep sediments to the overarching objectives of the remedial investigation should be evaluated with EPA.	Measurements of the extent, thickness, and general physical and chemical properties of sediments within the upper 30 feet of the pit lake surface. Chemical relationships between sediment solid phase and overlying pit water quality. The biological characteristics of the sediments along the pit lake shore to assess potential effects on the food web associated with the lake.	The study area boundary, as previously described in DQO #1, is applicable without modification to this DQO. The vertical extent of this DQO is within 30 feet of the pit lake surface.	The suite of analytical parameters for sediments will be consistent with those developed for the Process Areas RI Work Plan. All analyses and data collection will be consistent with the Site QAPP. Supplemental analyses that may be performed include sediment grain size, total organic carbon, and redox conditions.	Sediment sample collection and analytical data acceptance criteria will be in accordance with the approved Site QAPP and SOPs specific to this Pit Lake RI Work Plan. Laboratory minimum detection limits will be consistent with those identified in the Site QAPP and for other RI Work Plans approved by EPA (i.e., best available EPA-approved methods will be used for all analyses for both media).	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities including: ▪ Collection of water and sediment samples for chemical and biological analysis within the upper 30 feet of the pit lake surface. ▪ Integration of collected data with results from FSAP activities under DQO #6.

Table 4-1. Data Quality Objective Steps

DQO	Step 1 Problem Statement	Step 2 Identify Study Goals	Step 3 Identify Information Inputs	Step 4 Study Boundaries	Step 5 Develop The Analytical Approach	Step 6 Specify Performance or Acceptance Criteria	Step 7 Develop the Plan For Obtaining Data
DQO #6 – Biological Productivity of the Pit Lake	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. The nature of pelagic biomass, biological productivity and nutrient pathways in the pit lake are unknown, and the influence of surface biological activity on the nutrient budget and trace metal cycling of pit lake surface water is uncertain.	Characterize the pit lake pelagic zone and community (e.g., biomass, assemblages of pelagic organisms including fish), biological productivity and nutrient pathways in the pit lake.	Identification and characterization of assemblages of pelagic organisms, pelagic biomass, surface water nutrients, and biological uptake.	The study area boundary, as previously described in DQO #1, is applicable without modification to this DQO.	Determine the seasonal trophic status and nature of the photic zone in the pit lake using a Secchi disk. Determine chlorophyll-a using spectro-photometric methods for samples in the lake photic zone, the extent of which is to be derived from the Secchi disk measurements.	Determine the degree of correlation of pit lake biota and chemical concentrations, if any, in the photic zone and between the pit lake and other adjacent water sources (i.e., the Walker River and highwall seeps) to predict the biological character of the pit lake at "steady state" conditions.	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities including: ▪ Conducting a Secchi disk survey to determine the transparency and trophic status of the pit lake. ▪ Collection of surface water samples for analysis of chlorophyll-a and dissolved nutrients.
DQO #7 – Water Quality Characteristics Including the Prediction of "Steady-State" Water Quality Conditions	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. Long-term "steady state" water quality characteristics of the pit lake, with expected seasonal variations, are uncertain and cannot be predicted based on existing data.	Predict "steady state" water quality characteristics of the pit lake based on the results of activities proposed in DQOs #1 through #7, including seasonal variability and changes with depth under stratified or lake turnover conditions. The evolution of pit lake chemistry over time will be evaluated using existing and newly acquired data, including up to three years of monitoring following the completion of the FSAP described in this Pit Lake RI Work Plan.	Results of selected activities proposed in DQOs #1 through #6. Major, minor, and trace element concentrations in the pit lake water column and the groundwater monitoring well network.	The study area boundary, as previously described in DQO #1, is applicable without modification to this DQO.	Based on the results of the FSAP activities described in DQOs #1 through #6, including analytical modeling and calculations of the pit lake water balance and lake hydrodynamics, develop an approach to perform predictive geochemical modeling of the lake. Geochemical modeling may include analytical solutions (e.g., Lewis, 1999) and the use of one or more of the following programs: PHREEQC can be used for speciation and saturation-index calculations, batch-reaction and one-dimensional transport calculations. MINTEQA2 can be used for calculating the equilibrium mass distribution among dissolved and adsorbed species, and multiple solid phases. NETPATH can be used to interpret net geochemical mass-balance reactions between initial and final pit lake water along a hydrologic flow path, and can evaluate dissolution, precipitation, ion exchange, oxidation/reduction, degradation of organic compounds, mixing, evaporation and dilution processes.	Calibration of the predictive tools (analytical solutions and geochemical models) to simulate observed pit lake chemical and limnological conditions through the approximate five-year period of FSAP implementation and subsequent monitoring. Assessment of the sensitivity of various input parameters for water quality predictions (e.g., the relative importance of groundwater inflows to biological or limnological processes), and the identification of additional data needed to verify the importance of selected input parameters.	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities including selected data sets acquired as a result of DQOs #1 through #6.

Table 4-1. Data Quality Objective Steps

DQO	Step 1 Problem Statement	Step 2 Identify Study Goals	Step 3 Identify Information Inputs	Step 4 Study Boundaries	Step 5 Develop The Analytical Approach	Step 6 Specify Performance or Acceptance Criteria	Step 7 Develop the Plan For Obtaining Data
DQO #8 – Pit Lake Biota Characterization	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. The nature and composition of aquatic plant and animal species currently established in the littoral zone of the Yerington lake are unknown, and the use of these aquatic biota for food by higher trophic level semi-aquatic vertebrates (amphibians, birds, mammal s) is uncertain.	Document the nature and composition of the littoral community that is currently established in the pit lake, including the chemical composition of emergent plants.	Identification of of macrophytic vegetation, infaunal and epifaunal benthic invertebrates, and fish that may be present in the littoral zone.	The study area boundary, as previously described in DQO #1, is applicable with the modification that only the lake shorelines will be studied.	Standard limnological and ecological techniques for conducting surveys of shoreline habitat and biological assemblages in lakes and reservoirs (e.g., Lake and Reservoir Bioassessment and Biocriteria, EPA, 1998).	The number of samples needed to characterize within the littoral community varies depending on the assemblage of interest. The number and frequency of samples will follow the general guidelines provided by EPA (1998) for each of the major assemblages (e.g., fish, macrophytes, invertebrates).	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities.
DQO #9 – Upland Area Vegetation and Wildlife Habitat	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. Vegetative and wildlife habitat associated with riparian and upland sections of the pit lake shore and proximal highwall areas have not been characterized.	Document vegetative and wildlife habitat in riparian and upland areas of the lake basin and bordering areas within the operable unit.	Identification of vegetative habitat and communities associated with the riparian and upland areas of the lake basin and adjacent areas of the Pit Lake OU. Identification of wildlife habitat, wildlife migration corridors, and wildlife presence in the Yerington pit lake. Periodic observations of presence of wildlife species (birds, mammals) in pelagic, littoral, riparian and upland habitats.	The study area boundary, as previously described in DQO #1, is applicable with the modification to include large water bodies in west-central Nevada that may attract wildlife.	Wildlife habitat and presence of wildlife species will be documented using remote sensing techniques combined with standard survey and suitability indexing methods (e.g., Herrick *et al.* 2005, USFWS 1980). Qualitative observations on wildlife present will be recorded.	The number of habitat transects samples will be determined by the size of the potential habitats delineated by aerial orthographic quadrangle photograph analysis. The number of samples chosen will be adequate to allow statistical comparisons of site and reference transects at an alpha and beta of 0.1. Qualitative wildlife observations will be made to determine guilds of potential animals present at the pit lake and the extent of their access to various site media.	Historic and ongoing observational site wildlife data will be used to characterize the wildlife present at the pit lake. Historic data will be used to assess wildlife present at reference areas. Analysis of orthographic quadrangle photographs will initiate a field sampling plan design. Vegetative habitat and suitability indexi transect sampling will occurr when vegetation is in spring bloom to facilitate species identification.
DQO #10 – Screening Level Ecological Risk Assessment	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. Ecological risk associated with the existing or future pit lake under "steady state" conditions is currently unknown.	Assess potential ecological risk to aquatic organisms and to wildlife associated with pelagic, littoral, riparian, and upland zones of the lake basin	Observations of aquatic habitat and assemblage of organisms as described in DQOs #5-#8 above. Predicted or measured concentrations of chemicals in water and sediments as described in DQOs #5 and #7 above. Observations of vegetative and wildlife habitat as describe in DQO#9 above. Measured concentrations of chemicals in upland soils.	The study area boundary, as previously described in DQO #1, is applicable with the modification to include large water bodies in west-central Nevada that may attract wildlife.	Analytical methods for characterizing aquatic habitat and assemblages are provided above in DQOs #5-#8. Methods for characterizing riparian and upland vegetative and wildlife habitat are described above in DQO #9.	A site-specific conceptual site model and screening level ecological risk assessment (SLERA) will be conducted pursuant to EPA guidance (1997, 2001).	Data and information to support this DQO include both historic data and new data that will be collected pursuant to this Pit Lake RI Work Plan, described in the FSAP, and subsequent monitoring activities

Table 4-1. Data Quality Objective Steps

DQO	Step 1 Problem Statement	Step 2 Identify Study Goals	Step 3 Identify Information Inputs	Step 4 Study Boundaries	Step 5 Develop The Analytical Approach	Step 6 Specify Performance or Acceptance Criteria	Step 7 Develop the Plan For Obtaining Data
DQO #11 - Human Health Risk Assessment	The general problem statement, as previously presented in DQO #1 is applicable without modification to this DQO. Human health risk associated with the existing or future pit lake under "steady state" conditions is currently unknown.	Estimate potential risks for exposure to chemicals in the pit lake to human receptors, either directly or via outflow to down-gradient groundwater. Identify possible human uses of the lake with the potential for direct contact with OU soils, sediment and surface water and harvest of biota.	Validated analytical sampling results for onsite media and site-specific background data for soil and groundwater. Revised human health site model that outlines exposure routes relevant to the pit lake. Exposure parameters for human exposure scenarios. Screening level values for the identification of COPCs protective of exposure routes applicable to the Process Areas from the following sources: EPA Soil Screening Levels (SSLs) for human health. These values will be supplemented by additional sources of information that may include ATSDR toxicological profiles. Risk Assessment Information System (RAIS). Human health toxicity values will be obtained from EPA's IRIS database and ATSDR toxicological profiles	The study area boundary, as previously described in DQO #1, is applicable.	If the HHRA indicates that complete exposure pathways and representative exposure point concentrations result in unacceptable risk, then the identified area presenting risk to receptors will be further evaluated in the feasibility study.	Risk estimates are generally upper-bound estimates of risk, which limits the potential for underestimating potential risks to receptors. Input from EPA is necessary to determine tolerable risk ranges/thresholds for human health.	EPA Region 9 toxicologists will be consulted to determine appropriate exposure parameters, screening levels, and tolerable risk thresholds.
DQO #12 – Pit Highwall Slope Stability	The general problem statement, as previously represented in DQO #1, is applicable without modification to this DQO. Existing geotechnical characteristics of the pit highwalls have not recently been evaluated and future slope stability conditions are uncertain. Such conditions might potentially affect pit lake limnology and geochemistry, and may also affect existing infrastructure around the pit perimeter and access to the pit lake along established ramps. Pit highwall stability conditions also affect health and safety practices for implementing characterization and monitoring activities described in this Pit Lake RI Work Plan.	Establish the geotechnical and slope stability characteristics of the existing pit highwalls and project future conditions.	Field observations of pit highwall geologic and slope stability conditions, and the collection of geotechnical data such as (e.g., rock mass and soils properties).	The study area boundary, as previously described in DQO #1, is applicable without modification to this DQO. The study area boundary may extend beyond the location of the pit wall perimeter to include areas of tension cracks and potential failure surfaces.	Evaluate existing geotechnical conditions using standard pit highwall slope stability techniques including field observations (i.e., tension crack measurements, analysis of scarps, hydrogeologic conditions, rock mass displacement monitoring, electronic distance measurements, etc.).	Field observations and geotechnical data will be evaluated using current mining industry practices.	The evaluation of pit wall stability will be performed as described in Section 5.0 of this Pit Lake RI Work Plan.

SECTION 5.0

FIELD SAMPLING AND ANALYSIS PLAN

Because of the inter-relationship between the water balance, limnological, geochemical and biological aspects of the DQOs, and the iterative nature of the remedial investigation for the Yerington Pit Lake, three phases of work are proposed for the FSAP activities designed to address the study objectives listed in Section 4.0. The first phase will consist of initial characterization activities and approximately one year of comprehensive monitoring that, in total, would require a nominal two-year period. The second phase will consist of data interpretation and analysis, followed by a Pit Lake RI Work Plan Addendum that recommends follow-up monitoring and additional investigations, if needed. The second phase of work is anticipated to require up to three years to accommodate anticipated monitoring. The third phase will consist of the preparation of the remedial investigation report and, if necessary, recommendations for longer-term monitoring. Associated human health and ecological risk elements of this Pit Lake RI Work Plan would also be performed as part of this phased approach. Each of the phases is described below, and in Sections 5.1 through 5.3 (in general, earlier phases are described in more detail than subsequent phases).

Phase 1 (2Q 2008 through 2Q 2010)

Phase 1 activities will include: 1) field investigations focused on the collection of hydrogeologic and groundwater flow data, water balance information, and limnologic and hydrodynamic characteristics of the pit lake; 2) collection of water quality samples from pit inflow sources and the pit lake, and the laboratory analyses of chemical concentrations from the collected samples; 3) field biological investigations and habitat surveys, and an analysis of potential ecological risk (described in detail in Appendix B); 4) an analysis of potential human health risk (described in detail in Appendix A); and 5) geotechnical field investigations and analysis of collected data to support the prediction of pit highwall stability conditions. The sub-phases listed below will be performed over a nominal two-year period, and are described in Section 5.1:

- Phase 1-1 Installation of groundwater monitor wells in the alluvial and bedrock flow systems in the area of the open pit to assess hydrogeologic characteristics, hydraulic relationships between the lake, and the alluvial and bedrock flow systems, and groundwater quality conditions. Where health and safety concerns related to slope stability are accomodated, drilling activities in the pit area for the monitor wells might also anticipated to provide geotechnical information about the alluvium and bedrock. Collection of groundwater samples.
- Phase 1-2 Collection of monthly groundwater elevation data from existing and new monitor wells in the pit area, and daily monitoring of pit lake water levels using the pressure transducer installed as part of the Second-Step HFA.
- Phase 1-3 Installation of flow measurement devices at accessible highwall seep locations, and monthly measurements of flow rates. Collection of water quality samples from accessible seeps.
- Phase 1-4 Installation of a meteorological station as close as practicable to the pit lake shore and the collection of climate data (i.e., precipitation, pan evaporation, relative humidity, solar radiation, and wind speed and direction data). Installation of a lake temperature recording device and collection of daily temperature measurements. Collection of pit lake water quality parameters and water quality samples.
- Phase 1-5 Collection of sediments from the uppermost submerged bench of the lake, within 30 feet of the surface, and the analyses of the chemical concentrations and chemical release potential of the sediments.
- Phase 1-6 Analysis of groundwater, pit lake water and highwall seeps for the water samples collected in other Phase 1 activities.
- Phase 1-7 Collection of biological data and habitat survey information, described in Appendix B of this Pit Lake RI Work Plan.
- Phase 1-8 Compilation of potential human health risk factors, described in Appendix A of this Pit Lake RI Work Plan.
- Phase 1-9 Compilation of existing geotechnical data, and the collection and analysis of additional pit highwall geotechnical data, to assess slope stability conditions and recommend appropriate highwall monitoring.

The field activities associated with this first phase of investigations are anticipated to begin during the second or third quarter of 2008. Therefore, this approximate two-year initial phase of work will likely be completed in mid-to-late 2010. ARC anticipates that select monitoring programs initiated during Phase 1 will continue without interruptions into Phase 2.

Phase 2 (4Q 2010 through 4Q 2013)

Phase 2 will consist of the following activities: 1) compilation of hydrogeologic, water balance, limnologic, geochemical, biological and geotechnical data obtained during the nominal two-year Phase 1 characterization and monitoring period; 2) preparation of a Data Summary Report that provides an interpretation of the compiled data including predictive analyses and/or modeling of pit lake "steady-state" conditions (i.e., hydraulic, limnological, geochemical and geotechnical conditions); and 3) preparation and submittal of a Pit Lake RI Work Plan Addendum that recommends the continuation of select monitoring activities and other field studies resulting from the analysis of Phase 1 activities.

ARC anticipates that: 1) the scope and duration of additional select monitoring and other investigations will be developed in conjunction with EPA; and 2) specific aspects of Phase 2 monitoring (e.g., groundwater elevations and pit lake levels, and groundwater and pit lake water quality) may continue for up to three years. The nominal three-year period has been established to confirm the conceptualized time frame for the pit lake to reach or closely approach hydraulic "steady-state" conditions (Figure 3-11 suggests that such conditions may be reached by 2015). ARC also anticipates that annual pit lake monitoring reports, analogous to, or in conjunction with, the Site-wide groundwater monitoring annual reports, will be submitted during the Phase 2 period. The sub-phases listed below are described in Section 5.2.

- Phase 2-1 Preparation of a Data Summary Report for Phase 1 activities, and a Pit Lake RI Work Plan Addendum that addresses Phase 2-2 and, potentially, Phase 2-3.
- Phase 2-2 Continued monitoring of some or all of the following additional parameters, as necessary: 1) groundwater elevations and pit lake levels; 2) pit lake and groundwater quality; 3) highwall seeps; 4) meteorological conditions; and 5) geotechnical parameters for highwall stability.
- Phase 2-3 Implementation of additional field investigations not anticipated in this Pit Lake RI Work Plan that may be determined to be necessary as a result of Phase 1 activities.

Phase 3 (1Q 2014 through 3Q 2014)

Phase 3 activities include the preparation of the Remedial Investigation (RI) Report, including the baseline HHRA and SLERA attached as appendices. ARC anticipates that the RI Report will include: 1) a summary of all pit lake investigations performed to date, including the information presented in the Phase 1 Data Summary Report and the results of monitoring conducted pursuant to the Pit Lake RI Work Plan Addendum; 2) updated predictive analyses (i.e., analytical solutions and/or modeling) of pit lake hydraulic, limnological, geochemical and geotechnical conditions will include a description of assumptions and revised input parameters that may differ from the information presented in the Phase 1 Data Summary Report; and 3) recommendations for continued or additional monitoring that would support the feasibility study for the Pit Lake OU. Anticipated Phase 3 activities are briefly described in Section 5.3.

- Phase 3-1 Preparation of a Remedial Investigation Report that includes the results of Phase 1 and Phase 2 activities and the baseline risk assessment reports.
- Phase 3-2 Continued monitoring, as required by EPA.

5.1 Phase 1 Activities

The Phase 1 activities listed above are described in the following sub-sections. To limit duplication of the information associated with the HHRA and SLERA Work Plans, which are provided in Appendices A and B, respectively, brief descriptions of these activities are presented below (in Sections 5.1.7 and 5.1.8). General descriptions of field sampling, analysis, and quality control procedures for the Site are discussed in detail in the revised QAPP. Additional QA/QC information pertinent to this Pit Lake RI Work Plan is provided in the following FSAP activity descriptions, as appropriate, and in Section 6.0.

5.1.1 Installation of Groundwater Monitor Wells

To understand the hydraulic relationship between the Yerington Pit Lake and the surrounding alluvial and bedrock groundwater flow systems and, ultimately, develop the pit lake water balance, additional groundwater monitor wells will be installed around the perimeter of the pit to complement existing bedrock and alluvial wells in the area of the pit. Figure 5-1 shows the locations of the proposed and existing wells and Table 5-1 provides the rationale for their installation.

The well locations close to the pit depicted in Figure 5-1 are also superimposed on the bedrock structural element map developed by Seegmiller (1979), presented as Figure 5-2. In general, the proposed well locations have been selected to reflect the structural geology exposed in the pit, including the potential for the compartmentalization of groundwater, and the conceptualized recharge sources of groundwater into the pit from the Walker River and, to a lesser degree, the Singatse Range. From a practical standpoint, well locations have also been selected on the basis of health and safety considerations, potential longevity, and relative distance from existing wells that are proposed for continued monitoring in the pit area.

The well designations in Table 5-1 are consistent with the information provided in a letter from ARC to EPA dated October 4, 2007 with the subject heading: *Proposed Modifications to Groundwater Monitor Well Designations, Yerington Mine Site, Lyon County, Nevada*. Existing wells proposed to be used to evaluate groundwater flow and/or water quality conditions in the pit area, shown in Figure 5-1, include

- Shallow and deep alluvial wells at the B/W-23 location west of Weed Heights, constructed as part of the Second- Step HFA;
- Bedrock wells WW-59, WW-40 and WW-36 (former dewatering wells);
- Alluvial wells B/W-14, B/W-15, B/W-21 and B/W-23 constructed between the pit and the Walker River as part of the Second- Step HFA; and
- Piezometers WRP-1 and WRP-2 located adjacent to the Walker River, constructed as part of the Second- Step HFA.

Table 5-1. Rationale for Additional Pit Lake Area Monitor Wells

Well Identification	Rationale
PLMW-1B	Bedrock well located on the hanging wall of the Sericite Fault, a major structural element characterized by a wide fractured zone, a northeast-trending fault zone that dips NW at 50-70 degrees. The screen interval of this well is designed to penetrate groundwater within the hanging wall of the fault, which may be compartmentalized from Walker River recharge.
PLMW-2B	Bedrock well located immediately east of the pit, north of the channel cut by the 1997 flood diversion, and west of the Walker River in the area of the range front fault (it is likely the well will penetrate the fault). In conjunction with nearby alluvial piezometers, this will provide the best evidence for the Walker River recharge source concept and a potential gradient into the pit relative to existing well WW-40 (discounting effects of WW-36 pumping).
PLMW-3B	Bedrock well located on the south pit access ramp about 60 feet above the current pit lake surface. This location is within the footwall of the Sericite Fault and along the strike of an unnamed northeast-trending fault zone, and will provide groundwater data (elevations and quality) immediately adjacent to the pit lake. In conjunction with PLMW-4, this location will also characterize the groundwater gradient into the pit lake from the south.
PLMW-4B	Bedrock well located on the south pit perimeter, within the footwall of the Sericite Fault and along the strike of an unnamed northwest-trending fault. In conjunction with PLMW-3B, this location will characterize the groundwater gradient into the pit lake from the south.
PLMW-5B	Bedrock well located on the northwest pit perimeter adjacent to Burch Drive and behind the west highwall seeps along the strike of a mapped fault mapped in the pit (the steeply dips from 70-90 degrees, and brings volcanic rocks in contact with the copper porphyry). An adjacent alluvial well at this location (PLMW-1) will provide a comparison of the two flow systems in an area where recharge from the Singatse Range likely occurs.
PLMW-6B	Bedrock well located further to the northwest than PLMW-5, and adjacent to existing alluvial wells at the B/W-23 location. This location will provide a comparison of the two flow systems in an area where recharge from the Singatse Range likely occurs.
PLMW-7B	Bedrock well located north of existing wells WW-36 and WW-40 to evaluate the groundwater flow gradient into the pit sourced by the Walker River, generally from the east. This location may be close to, or beyond, the current hydraulic capture zone of the pit lake cone-of-depression.
PLMW-8	Alluvial well located on the northwest pit perimeter adjacent to Burch Drive and behind the west highwall seeps. The seeps may be recharged from both the Singatse Range and seepage from Weed Heights. In addition, the pit lake surface has intercepted the bedrock alluvial contact below this location, and the pit lake is conceptualized to recharge the alluvial aquifer immediately above the bedrock contact.
PLMW-9	Alluvial well located adjacent to existing bedrock well WW-59 to provide a comparison of the two flow systems in an area where potential recharge to the alluvial aquifer from the pit lake has the potential to migrate to the north of the pit. The borehole at this location will be drilled to the anticipated alluvial/bedrock contact to improve understanding of this geologic contact.

ARC anticipates that the monitor well network that includes the wells described in Table 5-1 and the existing wells listed above will be adequate to satisfy DQO #2 listed in Table 4-1. Additional monitor wells may be added to the network based on the information presented in the Phase 1 Data Summary Report.

Monitor Well Drilling

Drilling of bedrock monitor wells will be conducted using a dual-wall reverse circulation drilling rig equipped with the capability to drill through the alluvial cover using flooded-reverse methods, which can then be converted to drilling with air once bedrock has been reached. The use of flooded-reverse drilling with standard drilling mud will maintain the stability of the borehole through the alluvial formation. Once bedrock has been reached, the drill rig will convert to air as the fluid medium in order to: 1) allow for lithologic logging of the chips; 2) air-lift water from the bedrock to determine where groundwater occurs, which will assist in the design of the screen interval; and 3) facilitate development of the well once it is constructed. If the location of a bedrock groundwater monitor well coincides with a proposed geotechnical borehole location, the proposed drilling may be modified to accommodate both needs.

Drilling of alluvial monitor wells will use a sonic core drilling rig equipped with a continuous core barrel to facilitate detailed lithologic logging of aquifer materials and to determine water-bearing horizons within the formation. Drilling procedures will be consistent with EPA-approved procedures presented in the Second-Step HFA Work Plan.

Lithologic Logging

Fluid reverse drilling through the alluvial overburden for bedrock monitor wells precludes any lithologic logging of the alluvial materials. For the bedrock portion of these boreholes, lithologic logging of chips derived from reverse circulation drilling with air will performed on five-foot depth intervals. Lithologic types (e.g., volcanic, porphyry, etc.) and any alteration or structural features that may provide insight to the geologic character of the formation will be noted in the logs. Because fractured bedrock without clays are likely to transmit groundwater, the presence or absence of clay materials will also be noted in the lithologic logs. Chip samples will be archived at the Site in chip trays.

For alluvial monitor wells drilled with the sonic core method, alluvial materials will be described in general accordance with the American Society of Testing and Materials ("ASTM", 1992) Standard D 2487-92 – Classification of Soils for Engineering Purposes (Unified Soil Classification System or "USCS"). Core samples will be archived at the Site in core boxes to preserve their soil texture.

Well Construction Methods

All monitor wells would be constructed to allow for the collection of groundwater elevation measurements and groundwater quality samples. Monitor wells will be constructed with a nominal 15-foot long, 6-inch diameter steel surface casing, and 2-inch diameter schedule 40 polyvinyl chloride ("PVC") tubing as the blank (i.e., not screened) portion of the well. Approximately three feet of the steel surface casing will stick up above the ground surface to protect the plastic tubing of the monitor well.

A 20-foot, 0.020-inch slotted screen constructed of schedule 40 PVC will be installed at the design interval. A 2-inch flush-threaded PVC end cap will be placed at the bottom of the screened interval. Where necessary, beneath the water table, the borehole beneath the screen and bottom cap will be filled with fully hydrated bentonite grout (nominally 0.375-inch pellets) to three feet below the bottom of the well. Bentonite will be installed via tremmie pipe. Filter pack will begin at the top of the bentonite.

A filter pack consisting of 10/20 silica sand will be placed against the well screen and will extend approximately 3 feet above the top of the screen interval (i.e., 23 feet of filter pack placed in the annulus). Filter pack will be installed via tremmie pipe. A minimum one-foot thick layer of finer filter-pack sand material will be placed on top of the coarser filter pack to limit cement grout intrusion. A cement seal will then be placed in the annular space from the top of the filter pack to ground surface.

A locking 6-inch diameter well monument will be installed with a stick-up of approximately three feet above ground surface. A nominal 6-inch thick, 2-foot by 2-foot concrete slab will be placed around the surface casing. The well monument will contain the name of the monitor well. A Nevada-registered surveyor will be employed to survey the horizontal and vertical locations of each new monitor well, including the ground surface and top-of-casing elevations. The reference measurement point for depth-to-water measurements will be permanently marked on the top of the interior PVC casing, and will be surveyed within +/-0.01 foot in relation to mean sea level and to within +/- 0.05 foot relative to Nevada State Plane West Zone coordinates (NAD 27).

Well Development Methods

After the bentonite grout and cement surface seal has cured, each monitor well will be developed to remove fine-grained material from the well and to improve the hydraulic connection to the screened portion of the alluvial aquifer. Development procedures will include surging the well and periodically pumping or bailing fine grained material until the turbidity of the discharge water is less than or equal to 10 NTUs or has stabilized (i.e., varies less than +/- 10% over three successive casing volumes).

Well Sampling Methods

Groundwater monitor wells installed as part of this Pit Lake RI Work Plan will be sampled for dissolved constituents pursuant to the Site QAPP (ESI and Brown and Caldwell, 2007), the *Draft Site-Wide Groundwater Monitoring Plan* dated August 8, 2007, and EPA guidance (EPA 1996 and 2002b), per the following procedures:

- The pumping system would be prepared for operation by connecting the tubing to the in-line water quality meter and lowering the pump and tubing into the well, with the intake positioned at the approximate middle of the well screen.

- Commence well purging by low-flow pumping from the well at a flow rate not to exceed 500 ml/min. Initially a flow rate between 200 and 500 ml/min would be used. Efforts would be made to minimize generation of air bubbles in the sampling tubing by either increasing the flow rate as appropriate, or restricting the flow by clamping the tube. The purge rate would be recorded in the field logbook or field sampling form. Purging will continue until parameters have stabilized and a minimum of one screen volume of water is removed.
- Ideally, drawdown in the well should not exceed 0.3 feet. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump to help allow parameter stabilization.
- During purging, field parameters would be monitored and recorded including pH, conductivity, temperature, ORP and dissolved oxygen at time intervals sufficient to evacuate the volume of the flow-through cell, which would be calculated by dividing the volume of the flow-through cell by the pumping rate.
- Well sampling can commence after equilibration of water quality parameters. Equilibrated trends are generally obvious and usually follow either an exponential decay or asymptotic trend during purging.
- If the indicator field parameters have not stabilized after one hour of purging, then discontinue purging and collect the groundwater samples.
- At a minimum, at least two screen volumes should be purged prior to collecting a sample.

Equilibration is defined as three consecutive water quality parameter readings that meet the following EPA guidelines:

- Temperature is ± 3% RPD
- pH is ± 0.1 standard pH unit
- Conductivity is ± 3% RPD
- ORP is ± 20 mV
- DO is ± 10% RPD when DO exceeds 1 mg/L; ± 0.3 mg/L when DO < 1 mg/L
- Turbidity is ± 10% RPD when turbidity exceeds 10 NTUs.

Additional procedures to address high turbidity and improve the reliability of field stabilization data include:

1. Prior to connection to the flow cell, purge one screen volume from well.

2. Collect a water sample and measure and record its turbidity. If turbidity is <30 NTU, connect to flow cell and begin measuring and recording stabilization parameters. If turbidity is >30 NTU, install an in-line pre-filter(s) prior to connection to flow cell and begin measuring and recording stabilization parameters.
3. Following purging of a second screen volume and achievement of well stabilization according to field parameter readings, disconnect from flow cell and disconnect pre-filter(s). Collect a water sample and measure and record its turbidity.
4. Collect unfiltered and filtered water samples according to requirements for laboratory analyses.

After the initial sampling event conducted at the nine new monitor wells in the pit area, these wells would then be included in the quarterly monitoring program performed by ARC. The constituent list to be analyzed for during subsequent quarterly sampling events is described in Section 5.1.6, as are sample handling, labeling and preservation methods.

5.1.2 Groundwater Elevation and Pit Lake Level Measurements

Groundwater elevation measurements will be made in accordance with the *Draft Site-Wide Groundwater Monitoring Plan* dated August 8, 2007, which is currently under review by EPA. Measurements will either be obtained using a reel-mounted electrical sounding tape or by pressure transducer. ARC anticipates that two of the new monitor wells installed close to the pit lake will be equipped with pressure transducers and data loggers to match the pressure transducer installed in the pit lake as part of the Second-Step HFA.

The pressure transducer installed in the pit lake in September 2007, pursuant to the Second-Step HFA Work Plan, is an SPXD 600/10 Serial Digital Interface Submersible Pressure Transducer manufactured by KWK Technologies. The transducer is positioned inside a 1.5 inch diameter PVC electrical conduit, which is anchored to the access ramp to ensure a stable position for accurate measurements. The pressure transducer is attached to a 200-foot data cable that leads to a data logger, also installed on the south pit access ramp. Additionally, three survey posts with one-foot increments were installed on the ramp to verify the pressure transducer data. Photos of the installation are provided in Appendix E, and specifications for the instrument are provided in Appendix I.

The transducer was installed 2.83 feet below the pit lake level on September 26, 2007, which at the time was surveyed to be 4,212.3 feet amsl. The transducer records readings hourly and stores the data on a data logger, which will be downloaded approximately once per month and visually cross checked with the survey markers. The data logger is positioned 180 feet up the ramp at a location about 26 feet higher in elevation than the current lake level. At the current refilling rate of approximately five feet per year, the pressure transducer and data logger will need to be re-located in five years.

5.1.3 Highwall Seep Measurements

Two areas of significant seepage are visible in the Yerington Pit highwalls. The east highwall seep is dominated by recharge from the Walker River, which enters the pit approximately 30 feet below the top of the pit wall at the alluvium-bedrock contact in the erosion channel created during the 1997 flood diversion (Figure 5-3). The seep in this area generally comes from a single source and is consolidated into a flowing stream that follows an established channel from its source near the top of the highwall to the point where it enters the pit lake. Hershey (2002) measured flows from this source that varied seasonally between 100 and 120 gpm. ARC proposes to measure the east highwall seep flow rate on a monthly basis for a nominal two-year period, with additional monitoring to be determined on the results of Phase 1 monitoring.

EPA guidance on selecting appropriate flow measurement methods for various applications at mine sites (*Performing Quality Flow Measurements at Mine Sites*; EPA, 2001) recommends gauges, weirs, flumes, acoustic velocity meters, and tracer and dye dilution methods for such measurements. A cutthroat flume manufactured by Baski, Inc. (specifications provided in Appendix I) was determined to be the most feasible method for measuring east highwall seep flows. This device has: 1) converging wing walls, which are used to consolidate and divert a wider channel of an open stream to funnel it through the throat of the flume; 2) a flat floor which allows sediment and debris to easily pass through; and 3) a fixed-size throat with staff gauges affixed vertically to the sides in front of the throat and behind the throat.

A cutthroat flume of this type, with an 8-inch throat width, has the capacity to measure flow rates between 20 and 1,000 gpm, which is adequate for this seep. Proper placement of the flume is important to get accurate flow rate measurements (Driscoll, 1986). The following guidelines will be followed when placing the flume:

- The flume should be located in a straight stretch of the channel (no bends immediately upstream) and should be relatively flat for 4 to 6 feet upstream.
- The water should be relatively free of turbulence and waves; high approach velocities should be avoided.
- Because flow will be restricted in the flume, the channel upstream should have banks high enough to contain the flow.
- The channel approaching the flume should be regularly shaped so that flow is well distributed in the approach channel.
- Excessive submergence of the flume throat caused by backwater downstream should be avoided.

The flume will be placed in the main channel of the east highwall seep at a location near where the stream enters the pit lake, or any other location that meets the placement requirements listed above. This will ensure that the full flow of the stream is being included in the measurement. If this area becomes submerged before the nominal two-year monitoring period is completed, the flume will need to be re-located to another suitable location that may be safely accessed.

The west highwall seep is located beneath the Community of Weed Heights, and is spread over an area approximately 500 feet long. This seep may consist of two or three sub-areas, based on occurrence of vegetation (Figure 5-3). The base of the vegetation and seep is the bedrock-alluvium contact, with vegetation occurring approximately 75 feet above the contact. Although it is unlikely that a single identifiable stream is available for measuring flow rates in this area, Hershey (2002) reports flow rates up to 50 gpm. Because this area has not been subject to a close-up inspection prior to the development of this Pit Lake RI Work Plan, as it is only accessible by a boat or raft, a close-up examination of the area will be required to determine the suitability and appropriate methods for measuring seep flow rates in this area.

Based on observed conditions, ARC anticipates that quantitative measurements of flow rates for the west highwall seep will be difficult to obtain, primarily due to the broad area of seepage with a number of small seeps and the steepness of the pit wall in this area. This location has limited or no access to the upper reaches of the seep, and the base of the seep can only be reached by boat. The original base of this seep has been submerged by the pit lake, presumably since 2005 or 2006. For these reasons, quantitative methods for measuring flows do not appear applicable nor practical (e.g., the use of flow meters, weirs and flumes require a stable channel with low-gradient sections, and diversions and tracer/dye dilution methods are not feasible because of the limited access). If the east highwall seeps can be accessed by boat or raft, a qualitative visual flow estimate can be made or flow rates may be calculated by measuring the time it takes to fill a five-gallon bucket at suitable seepage sites.

5.1.4 Meteorological and Limological Measurements

Limnological data required to support the hydrodynamic analysis of the Yerington Pit Lake includes the following:

- Meteorological data;
- Pit lake level and pit water surface temperature measurements; and
- Depth-discrete sampling and analysis of water quality in the lake water column.

These data will be integrated with other aspects of the pit water balance in the Data Summary Report, as part of the Phase 2 activities.

Meteorological Monitoring

One of the meteorological stations currently being used to evaluate meteorological conditions at the Site in conjunction with the existing air quality monitoring ("AQM") program will be re-located to an accessible location adjacent to, or as close as possible to, the pit lake shore. ARC anticipates that, by the time this Pit Lake RI Work Plan is implemented, the AQM program will have reached its conclusion and one of the meteorological stations will be available for the remedial investigation of the pit lake. The location of the meteorological station will take into account the recent pit lake level increase up to five feet per year. The near-shore location is necessary to measure local meteorological conditions such as wind speed and direction, ambient temperature, relative humidity, barometric pressure, solar radiation, and precipitation. The following instrumentation and equipment, or similar, will be used at the pit lake meteorological station.

- RM Young 05305 Wind Monitor-AQ sensors for measuring wind speed and direction. This model is specifically designed for air quality measurements and according to Campbell Scientific, meets or exceeds requirements published by the EPA. The instrument is rated for wind speeds between 0 to 90 miles/hour and single gusts of 100 miles/hour.
- Vaisala HMP45C Temperature/Relative Humidity probe and RM Young 12-plate gill solar radiation shield.
- Vaisala CS105 Barometric Pressure Sensor PTB101B.
- Kipp & Zonen Silicon Pyranometer for measuring solar radiation.
- Texas Electronics TE525WS 8-inch Rain Gage with tipping bucket (0.01 tip) was upgraded with a CS705 heated snowfall adapter.
- CR10X measurement control and data logger and PC208W data logger software.
- Campbell Scientific PS100 power supply with 12V charging regulator, sealed rechargeable battery, and 18V 1.2A wall charger.

The following meteorological variables will be recorded and downloaded in conjunction with monthly sampling and profiling of the pit lake water:

- Precipitation in inches;
- Temperature in degrees Celsius (ºC);
- Relative humidity in percent;
- Barometric pressure in milliBars (mBar);
- Solar radiation in kiloJoules per square meter (kJ/m^2);
- Wind speed in meters per second (m/s); and
- Wind direction in degrees.

The meteorological station data logger will be programmed to sample every two seconds and record data every 15 minutes. At hourly intervals, the data logger calculates and records summary data (e.g., sum of precipitation readings) for the previous hour.

Pit Water Surface Temperature Measurements

Pit lake surface temperature measurements will be obtained using a self-contained HOBO thermistor and data logger, to be deployed at the pit lake sampling station described below, and shown in Figure 5-3. The internally powered and self recording thermistor will be housed in a 0.7- x 4-inch stainless steel cylinder, and will have an accuracy of +/- 0.22 ^{o}C. Hourly water temperature measurements from approximately three feet below the water surface will be collected, and recorded by the internal data logger. The thermistor data will serve as input for the empirical relationships discussed in Section 5.2. The data will also precisely determine when and how often the lake water column overturns, manifested as a sudden decrease in epilimnitic water temperature due to mixing with colder, hypolimnitic water.

Pit Lake Water Parameter Measurements and Water Quality Sampling

Understanding the limnology of the Yerington Pit Lake requires the collection of pit water samples that: 1) represent the entire water column; and 2) are not affected by various near-shore effects. The littoral (i.e., shore) zones of lakes tend to have thermal, chemical, and biological characteristics that do not necessarily represent the main water mass of a lake (e.g., Hutchison, 1975; Klaff, 2002). Therefore, in order to obtain representative water samples from the entire water column, a permanently moored ‘pit lake sampling station’ above the deepest portion of the lake will be established to provide adequate and reproducible water quality data. The sampling station will consist of a prominent buoy moored by a 50-pound fluke anchor in the deepest portion of the pit lake, as determined by a hand held GPS unit. The sampling station will be accessed with a motorized boat or raft, stored on Site, capable of carrying two people plus pumps, sampling gear, laptop computer and multi-sensor probe.

Field parameter data will be collected using a multi-sensor Hydrolab MS5 probe (or equivalent) to measure temperature, conductivity, pH, oxidation reduction potential (ORP), and dissolved oxygen (DO). The Hydrolab unit has a depth sensor to eliminate the need of using marked rope of chain to determine depth, which can produce errors due to the drift resulting from currents. Hydrolab sensor accuracy is provided for the parameters listed below:

- Temperature: ±0.10 ^{o}C
- Depth: ±.05 m
- Conductivity: ±.001 mS/cm
- ORP: ±20 mV
- DO: ±0.1 mg/L @< 8mg/L; ±0.2 mg/L @>8mg/L;
- pH: . ±01 pH unit

The measurement of pit water field parameters at depth, and the collection of depth-specific water quality samples, from the pit lake sampling station will be performed for a nominal one-year period, according to the schedule provided in Table 5-2. ARC recognizes that, based on the analytical results obtained during the first year of monitoring, EPA may request additional measurements of pit water field parameters.

Table 5-2. Schedule for Pit Lake Water Quality Parameters and Samples

	Hydrolab Measurements of Water Quality Parameters	Collection of Pit Lake Water Samples (water column, near-shore and seeps)
Sample depths	Every 10 feet in the upper 100 feet of the water column; and every 20 feet from 100 feet to total depth	Every 25 feet in the upper 100 feet of the water column; every 50 ft from 100 ft to total depth
Approximate sampling dates	Six per year: mid January, March, April, July, October, and November	Four per year: mid January, April, July, and October

Table 5-2 describes a greater frequency for the measurement of pit water field parameters than for water quality sampling because temperature and DO are important parameters for understanding the physical limnology of the pit lake, and are required inputs for potential hydrodynamic numerical modeling. The proposed pit water field parameter measurement schedule emphasizes the spring and fall because the onset of lake stratification and turnover occur during these seasons, respectively.

The Hydrolab multi-sensor probe will be calibrated at the beginning of each sampling period using standard solutions provided by a vendor, and instructions provided by the instrument manufacturer. These activities will be documented in field notebooks according to the QAPP. In conjunction with the field parameter measurements using the Hydrolab multi-sensor probe, water samples will be collected from the pit lake water column for the analysis of additional field parameters and for laboratory analyses. Table 5-3 provides the field data to be collected from the Hydrolab probe, field kit analyses and a laboratory analysis for total organic carbon (TOC).

Table 5-3. Proposed Field and Analytical Requirements for Pit Lake Water Quality Parameters

Measurement / Parameter	Field / Laboratory	Method	Measurement / Detection Limit	Units
pH	Hydrolab Sensor	EPA 150.1, Meter	0.1	Standard Unit
Conductivity	Hydrolab Sensor	EPA 150.1, Meter	1	uS/cm
Temperature	Hydrolab Sensor	Standard Methods 212, Thermometer	0.1	^{o}Centigrade
Dissolved Oxygen (DO)	Hydrolab Sensor	EPA 360.1, Probe	0.1	mg/L
Oxidation-Reduction Potential (ORP)	Hydrolab Sensor	SM 2580 B	1	mV
Iron (Total)	CHEMetrics, Inc Water Analysis Kit	CHEMetrics, Inc Method K-6010, Colorimetric	0.02 – 3.0	mg/L
Iron (Ferrous)	CHEMetrics, Inc Water Analysis Kit	CHEMetrics, Inc Method K-6010, Colorimetric	0.02 – 3.0	mg/L
Sulfate	HACH Field Water Analysis Kit	HACH Method 8051 (SulfaVer 4 Method)	2	mg/L
Alkalinity as $CaCO_3$	HACH Field Water Analysis Kit	HACH Method 8203 (Phenolphthalein Method)	10	mg/L
Total Organic Carbon (TOC)	Laboratory	EPA 415.1 (combustion/oxidation)	2.0	mg/L

Samples for the field and laboratory analyses presented in Table 5-3 will be collected using a weighted, approximate 0.5-inch diameter sampling tube connected to a peristaltic pump. Volume-based criteria require that a minimum of two times the volume of water in the sample tube between the sample level and the surface be purged prior to sample collection. Once the volumetric criteria are met, a 0.45 um in-line filter will be connected to the sample tube to allow collection of a water sample for field measurements of sulfate utilizing a HACH DR/2400 portable lab spectrophotometer, total alkalinity using a HACH alkalinity titration kit, and total iron and ferrous iron using a CHEMetrics, Inc. colorimetric field analysis kit. A split of each depth-specific water sample will be sent to the analytical laboratory for the analysis of TOC.

Field measurements of sulfate and total alkalinity will be made in accordance with HACH Methods 8051 and 8203, respectively. Total and ferrous iron will be made in accordance with CHEMetrics, Inc. Method K-6010. The results of the field kit field measurements will be recorded on field sampling forms. Accuracy of the field analyses will be achieved by using the Standard Solution Method for sulfate and the Standard Additions Method for alkalinity, as recommended by the manufacturer. Standard solutions will be created during each sampling trip for total iron and sulfate, and will be used to adjust the spectrophotometer to the standard solution prior to each analysis. Accuracy of the total and ferrous iron field measurements will be achieved using the colorimetric reference standards provided by CHEMetrics with the field kit.

In addition to the measurements and analyses described above, depth-specific samples of the pit lake water column will be collected for both total (i.e., unfiltered) and dissolved (i.e., filtered) chemicals listed in Section 5.1.6. Typically, the unfiltered samples will be collected after the filtered samples are collected using the same 0.5-inch diameter sampling tube connected to a peristaltic pump. Purge techniques and QA/QC procedures will be in accordance with Section 6.0 of this Pit Lake RI Work Plan and the Site QAPP. The rationale for analyzing for both total and dissolved chemicals from the entire water column is that the acquisition of a complete analytical profile of the pit lake water column during four seasons will provide the basis for a defensible evaluation of “steady-state” water quality conditions in the pit lake.

Pit lake water quality samples will also be collected from the near-shore zone at locations adjacent to the vegetated areas associated with the east and west highwall seeps, as shown in Figure 5-3, and at additional locations associated with macroinvertebrate and fish sampling in the littoral zone. Samples from these locations will be analyzed for total and dissolved chemicals, as described in Section 5.1.6. The rationale for analyzing for total and dissolved chemicals from the near-shore zone adjacent to the vegetated areas, is that these areas may provide habitat for water fowl and terrestrial wildlife, which would be evaluated for exposure to the total chemical, and, and could also provide shallow water habitat for emergent vegetation and aquatic macroinvertebrates, which would be evaluated for exposure to the dissolved chemical (see Appendix B). Sample collection and analysis is planned for one year, with samples collected according to the schedule provided in Table 5-2.

Samples will also be collected from the east and west highwall seeps (the west seep may have limited or no access, to be evaluated as part of Phase 1 activities), at the locations shown in Figure 5-3. Samples from these locations will be analyzed for total and dissolved chemicals, as described in Section 5.1.6. The rationale for analyzing for total and dissolved chemicals only from the east and west highwall seeps (west highwall seep if accessible) is that they: 1) support the vegetated areas, which may provide habitat for water fowl and terrestrial wildlife; and 2) could also support macroinvertebrates that colonize lentic (moving water) habitat, which may provide forage to higher trophic level consumers (see Appendix B). Sample collection and analysis from the seeps is also anticipated to be limited to one year, with samples collected according to the schedule provided in Table 5-2.

5.1.5 Collection and Analysis of Sediment Samples

Bottom sediments from the uppermost submerged bench, up to a depth of 30 feet of the lake surface, will be collected with a gravity corer (MSI Model 2171) at four locations around the perimeter of the lake, including the vegetated areas associated with the (accessible) highwall seeps (proposed sample locations are shown in Figure 5-3). Collection of core rather than a grab sample will allow vertical variations in sediment composition to be determined. Additional grab samples will be collected in shallow littoral habitat as described in Appendix B. The purpose of these samples will be to: 1) evaluate the nature of near-shore inputs (both organic and inorganic) to lake water quality; and 2) assess potential exposure and risk to benthic macroinvertebrates or fish that may have colonized the lake bottom (see Appendix B).

The sediment cores will be place into a plastic bag for lithologic logging. A portion of the core selected at 6-inch intervals will be sectioned off, quickly sealed with duct tape and placed in a second plastic bag. After labeling, the sample will be immediately placed on ice in a cooler and transferred as soon as possible to a freezer located onsite for freezing and temporary storage.

In addition, sediment samples will be collected from locations where the two access ramps enter the pit lake. Samples will be collected from no more than three feet below the water surface to characterize sediment that may be contacted by human receptors described in the HHRA Work Plan (Appendix A). Up to 10 grab sediment samples will be collected from a maximum depth interval of 0 to 10 centimeters (cm). Appropriate sample locations will be selected in the field in consultation with EPA staff. Grab sediment sampling protocols are described in Appendix B3.

The additional sediment and soil samples to be collected in support of the human health and ecological risk assessments are described in greater detail in Appendices A and B of this Pit Lake RI Work Plan. The analytical parameters for these additional sediment and soil samples are further described in the respective HHRA and SLERA Work Plans.

Soil Sampling

Surface soil samples will be collected from points at which humans would be likely to contact soil while accessing the pit lake. Sample collection activities will be focused on the two access roads leading down to the pit lake surface water. Up to 10 soil samples will be collected from 0 to 10 cm from each access road, according to methods described in the Site QAPP. Figure 5-3 includes preliminary soil sample locations; however, selection of sample locations will be ultimately determined in the field, in consultation with EPA staff.

Laboratory Analysis

Sediment and soil samples will be sent to the laboratory for the analysis of the chemicals listed in Table 5-4. Sample nomenclature, shipping protocols, and related QA/QC issues are addressed in Section 6.0 of this Pit Lake RI Work Plan pursuant to the Site QAPP.

Table 5-4. Proposed Analytes for Pit Lake Sediment and Soil Samples

Parameter or Analyte	Method	Reporting Limit	Units
Metals			
Aluminum	EPA 6010B	10	mg/Kg
Antimony	EPA 6020	1	mg/Kg
Arsenic	EPA 6020	0.5	mg/Kg
Barium	EPA 6020	0.5	mg/Kg
Beryllium	EPA 6020	0.3	mg/Kg
Boron	EPA 6010B	5	mg/Kg
Cadmium	EPA 6020	0.5	mg/Kg
Calcium	EPA 6010B	15	mg/Kg
Chromium	EPA 6020	1	mg/Kg
Cobalt	EPA 6020	0.5	mg/Kg
Copper	EPA 6020	1	mg/Kg
Iron	EPA 6010B	5	mg/Kg
Lead	EPA 6020	0.5	mg/Kg
Magnesium	EPA 6010B	10	mg/Kg
Manganese	EPA 6020	0.5	mg/Kg
Mercury	EPA 7471A	0.02	mg/Kg
Molybdenum	EPA 6020	1	mg/Kg
Nickel	EPA 6020	1	mg/Kg
Selenium	EPA 6020	1	mg/Kg
Thallium	EPA 6020	0.5	mg/Kg
Vanadium	EPA 6020	1	mg/Kg
Zinc	EPA 6020	10	mg/Kg
Radiochemicals			
Uranium, Total	EPA 6020	0.5	mg/Kg
Gross Alpha	EPA 9310	1.0	pCi/g
Gross Beta	EPA 9310	1.0	pCi/g
Radium-226	HASL 300	1.0	pCi/g
Radium-228	HASL 300	1.0	pCi/g
Thorium-228	Th-01 Modified	1.0	pCi/g
Thorium-230	Th-01 Modified	1.0	pCi/g

5.1.6 Analysis of Water Samples

As described above, water samples to be collected and analyzed as part of this Pit Lake RI Work Plan include groundwater from existing and new monitor wells, depth-specific water samples from the location of the pit lake sampling station, surface water samples from the pit lake shore at locations adjacent to potential habitat areas associated with vegetation on the east and west highwall areas, and seeps that flow into the pit lake from the east and west highwalls (the ability to collect seep samples form the west highwall is currently uncertain). Figure 5-3 depicts the proposed sample locations. The following rationale provides the basis for the analytical parameters proposed for these water sample sources, which are summarized in Table 5-5.

Groundwater from Existing and New Monitor Wells

Water quality analyses will be for physical parameters, major cations and anions, dissolved metals, and dissolved radiochemicals consistent with other groundwater investigations at the Site and the Site-Wide Groundwater Monitoring Plan (Brown and Caldwell and Norwest, 2007).

Depth-Specific Water Samples from the Pit Lake Sampling Station

Water quality analyses will be for physical parameters, major cations and anions, dissolved and total metals, and dissolved and total radiochemicals. The purpose of analyzing for dissolved and total metals, and dissolved and total radiochemicals for four quarters will be to compare overall pit lake water quality throughout the entire water column with: 1) the chemical characteristics of groundwater sources that are inflow sources into the pit lake; and 2) the chemical characteristics of surface water samples from the pit lake adjacent to potential habitat areas at the east and west highwall seeps. In addition, during the winter sampling event, which is most representative of annual average water quality conditions, the organic constituents presented in Table 5-5 will be analyzed for a sub-set of the water column profile (i.e., every 100 feet from the surface to total depth, including the pit lake surface). The list of organic constituents includes the same chemicals analyzed in groundwater samples collected from beneath the Process Areas, and is included in this Pit Lake RI Work Plan at the request of EPA's eco-toxicologist.

Surface Water Samples from the Pit Lake Adjacent to Potential Habitat Areas

Water quality analyses from pit lake samples collected from the potential habitat areas adjacent to the east and west highwall seeps will be for physical parameters, major cations and anions, and total metals and radiochemicals. For the reason described above, samples collected during the winter sampling event will include the list of organic constituents presented in Table 5-5.

Seep Flows into the Pit Lake From the East and West Highwalls

Water quality analyses for samples collected from the east and west highwall seeps (the west seep may not be accessible) will include physical parameters, major cations and anions, and total metals and radiochemicals.

Table 5-5. Proposed Analyte List for Water Samples

Parameter or Analyte	Total / Dissolved (1)	Method (2)	Reporting Limit (2)	Units	Monitor Wells	Pit Lake – Littoral Habitat	Pit Lake – Mid-Lake Water Column	Seeps
Physical Parameters and Major Anions/Cations: *All water samples*								
Alkalinity (Total as $CaCO_3$)	Total	SM 2320 B	2.0	mg/L	x	x	x	x
Bicarbonate	Total	SM 2320B	2.0	mg/L	x	x	x	x
Carbonate	Total	SM 2320B	2.0	mg/L	x	x	x	x
Chloride	Total	EPA 300.0	0.5	mg/L	x	x	x	x
Fluoride	Total	EPA 300.0	0.5	mg/L	x	x	x	x
Nitrate (NO_3 as N)	Total	EPA 300.0	0.15	mg/L	x	x	x	x
Nitrite (NO_2 as N)	Total	EPA 300.0	0.15	mg/L	x	x	x	x
Phosphorus, Total	Total	EPA 200.7	0.05	mg/L	x	x	x	x
Sulfate	Total	EPA 300.0	0.5	mg/L	x	x	x	x
pH	Total	SM 4500 H + B	0.01	pH Units	x	x	x	x
Total Dissolved Solids (TDS)	Total	SM 2540 C	10	mg/L	x	x	x	x
Total Organic Carbon (TOC)	Total	SM 5310C	1.0	mg/L	x	x	x	x
Dissolved Organic Carbon	Total	EPA 415.1	.05	mg/L	x	x	x	x
Ammonia	Total	EPA 350.1	0.05	mg/L	x	x	x	x
Chlorophyll-a	Total	SM 10200H	0.8	mg/L	x	x	x	x

Table 5-5. Proposed Analyte List for Water Samples - Continued								
Parameter or Analyte	**Total / Dissolved (1)**	**Method (2)**	**Reporting Limit (2)**	**Units**	**Monitor Wells**	**Pit Lake – Littoral Habitat**	**Pit Lake – Mid-Lake Water Column**	**Seeps**
Metals: *All water samples (total and/or dissolved depending on requirements)*								
Aluminum	Total(T)+Dissolved(D)	EPA 200.7	0.05	mg/L	D	T	T/D	T
Antimony	Total(T)+Dissolved(D)	EPA 200.8	0.002	mg/L	D	T	T/D	T
Arsenic	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Barium	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Beryllium	Total(T)+Dissolved(D)	EPA 200.8	0.0005	mg/L	D	T	T/D	T
Boron	Total(T)+Dissolved(D)	EPA 200.7	0.05	mg/L	D	T	T/D	T
Cadmium	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Calcium	Total(T)+Dissolved(D)	EPA 200.7	0.1	mg/L	D	T	T/D	T
Chromium	Total(T)+Dissolved(D)	EPA 200.8	0.002	mg/L	D	T	T/D	T
Cobalt	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Copper	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Iron	Total(T)+Dissolved(D)	EPA 200.7	0.04	mg/L	D	T	T/D	T
Lead	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Lithium	Total(T)+Dissolved(D)	EPA 200.7	0.05	mg/L	D	T	T/D	T
Magnesium	Total(T)+Dissolved(D)	EPA 200.7	0.02	mg/L	D	T	T/D	T
Manganese	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Mercury	Total(T)+Dissolved(D)	EPA 245.1	0.0002	mg/L	D	T	T/D	T
Molybdenum	Total(T)+Dissolved(D)	EPA 200.8	0.02	mg/L	D	T	T/D	T
Nickel	Total(T)+Dissolved(D)	EPA 200.8	0.002	mg/L	D	T	T/D	T
Potassium	Total(T)+Dissolved(D)	EPA 200.7	0.5	mg/L	D	T	T/D	T
Selenium	Total(T)+Dissolved(D)	EPA 200.8	0.002	mg/L	D	T	T/D	T
Silica	Total(T)+Dissolved(D)	EPA 200.7	0.05	mg/L	D	T	T/D	T
Silver	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Sodium	Total(T)+Dissolved(D)	EPA 200.7	0.5	mg/L	D	T	T/D	T
Strontium	Total(T)+Dissolved(D)	EPA 200.7	0.02	mg/L	D	T	T/D	T
Thallium	Total(T)+Dissolved(D)	EPA 200.7/200.8	0.01	mg/L	D	T	T/D	T
Tin	Total(T)+Dissolved(D)	EPA 200.7	0.1	mg/L	D	T	T/D	T
Titanium	Total(T)+Dissolved(D)	EPA 200.7	0.001	mg/L	D	T	T/D	T
Uranium, Total	Total(T)+Dissolved(D)	EPA 200.8	0.001	mg/L	D	T	T/D	T
Vanadium	Total(T)+Dissolved(D)	EPA 200.8	0.002	mg/L	D	T	T/D	T
Zinc	Total(T)+Dissolved(D)	EPA 200.8	0.01	mg/L	D	T	T/D	T

Table 5-5. Proposed Analyte List for Water Samples - Continued								
Parameter or Analyte	**Total / Dissolved (1)**	**Method (2)**	**Reporting Limit (2)**	**Units**	**Monitor Wells**	**Pit Lake – Littoral Habitat**	**Pit Lake – Mid-Lake Water Column**	**Seeps**
Radiochemicals: *All water samples*								
Gross Alpha	Total(T)+Dissolved(D)	EPA 900.0	3.0	pCi/L	D	T	T/D	T
Gross Beta	Total(T)+Dissolved(D)	EPA 900.0	4.0	pCi/L	D	T	T/D	T
Radium-226	Total(T)+Dissolved(D)	EPA 903.0	1.0	pCi/L	D	T	T/D	T
Radium-228	Total(T)+Dissolved(D)	EPA 904.0	1.0	pCi/L	D	T	T/D	T
Thorium-228	Total(T)+Dissolved(D)	EPA 907.0	1.0	pCi/L	D	T	T/D	T
Thorium-230	Total(T)+Dissolved(D)	EPA 907.0	1.0	pCi/L	D	T	T/D	T
Total Petroleum Hydrocarbons (TPH): *One-time analysis on Pit Lake samples*								
Diesel (C12-C23)-TPH	Total	8015B	500	µg/L	--	1 time	1 time	
Motor Oil (C23-C40)-TPH	Total	8015B	500	µg/L	--	1 time	1 time	
Gasoline (C4-C12)-TPH	Total	8015B	50	µg/L	--	1 time	1 time	
Volatile Organic Compounds (VOC): *One-time analysis on Pit Lake samples*								
Benzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Bromobenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Bromochloromethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
Bromodichloromethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
Bromoform	Total	8260B	1.0	µg/L	--	1 time	1 time	
Bromomethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
n-Butylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
sec-Butylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
tert-Butylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Carbon tetrachloride	Total	8260B	0.50	µg/L	--	1 time	1 time	
Chlorobenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Chloroethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
2-Chlorotoluene	Total	8260B	1.0	µg/L	--	1 time	1 time	
4-Chlorotoluene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Chloroform	Total	8260B	1.0	µg/L	--	1 time	1 time	
Chloromethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2-Dibromo-3-chloropropane	Total	8260B	5.0	µg/L	--	1 time	1 time	
Dibromochloromethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2-Dibromoethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
Dibromomethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2-Dichlorobenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,3-Dichlorobenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	

Table 5-5. Proposed Analyte List for Water Samples - Continued								
Parameter or Analyte	**Total / Dissolved (1)**	**Method (2)**	**Reporting Limit (2)**	**Units**	**Monitor Wells**	**Pit Lake – Littoral Habitat**	**Pit Lake – Mid-Lake Water Column**	**Seeps**
Volatile Organic Compounds (VOC): *One-time analysis on Pit Lake samples* - Continued								
1,4-Dichlorobenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Dichlorodifluoromethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,1-Dichloroethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2-Dichloroethane	Total	8260B	0.50	µg/L	--	1 time	1 time	
1,1-Dichloroethene	Total	8260B	1.0	µg/L	--	1 time	1 time	
cis-1,2-Dichloroethene	Total	8260B	1.0	µg/L	--	1 time	1 time	
trans-1,2-Dichloroethene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Dichlorofluoromethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2-Dichloropropane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,3-Dichloropropane	Total	8260B	1.0	µg/L	--	1 time	1 time	
2,2-Dichloropropane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,1-Dichloropropene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Ethylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Hexachlorobutadiene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Isopropylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
p-Isopropyltoluene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Methylene chloride	Total	8260B	1.0	µg/L	--	1 time	1 time	
Naphthalene	Total	8260B	1.0	µg/L	--	1 time	1 time	
n-Propylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Styrene	Total	8260B	1.0	µg/L	--	1 time	1 time	
tert-butyl methyl ether	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,1,2,2-Tetrachloroethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,1,2,2-Tetrachloroethene	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,1,1,2-Tetrachloroethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
Toluene	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2,3-Trichlorobenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2,4-Trichlorobenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,1,1-Trichloroethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,1,2-Trichloroethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
Trichloroethene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Trichlorofluoromethane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2,3-Trichloropropane	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,2,4-Trimethylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	
1,3,5-Trimethylbenzene	Total	8260B	1.0	µg/L	--	1 time	1 time	

Table 5-5. Proposed Analyte List for Water Samples – Continued

Parameter or Analyte	Total / Dissolved (1)	Method (2)	Reporting Limit (2)	Units	Monitor Wells	Pit Lake – Littoral Habitat	Pit Lake – Mid-Lake Water Column	Seeps
Volatile Organic Compounds (VOC): *One-time analysis on Pit Lake samples* - Continued								
Vinyl chloride	Total	8260B	0.50	µg/L	--	1 time	1 time	
Xylene (total)	Total	8260B	2.0	µg/L	--	1 time	1 time	
o-Xylene	Total	8260B	1.0	µg/L	--	1 time	1 time	
m-Xylene	Total	8260B	1.0	µg/L	--	1 time	1 time	
p-Xylene	Total	8260B	1.0	µg/L	--	1 time	1 time	
Semi-Volatile Organic Compounds (SVOC): *One-time analysis on Pit Lake samples*								
2-Chlorophenol	Total	8270C	10	µg/L	--	1 time	1 time	
4-Chloro-3-methylphenol	Total	8270C	20	µg/L	--	1 time	1 time	
2,4-Dichlorophenol	Total	8270C	10	µg/L	--	1 time	1 time	
2,4-Dimethylphenol	Total	8270C	20	µg/L	--	1 time	1 time	
2,4-Dintrophenol	Total	8270C	20	µg/L	--	1 time	1 time	
4,6-Dintiro-o-cresol	Total	8270C	20	µg/L	--	1 time	1 time	
2-Methylphenol	Total	8270C	10	µg/L	--	1 time	1 time	
3&4-Methylphenol	Total	8270C	10	µg/L	--	1 time	1 time	
2-Nitrophenol	Total	8270C	10	µg/L	--	1 time	1 time	
4-Nitrophenol	Total	8270C	10	µg/L	--	1 time	1 time	
Pentachlorophenol	Total	8270C	20	µg/L	--	1 time	1 time	
Phenol	Total	8270C	10	µg/L	--	1 time	1 time	
2,4,5-Trichlorophenol	Total	8270C	20	µg/L	--	1 time	1 time	
2,4,6-Trichlorophenol	Total	8270C	20	µg/L	--	1 time	1 time	
Acenaphthene	Total	8270C	10	µg/L	--	1 time	1 time	
Acenaphthylene	Total	8270C	10	µg/L	--	1 time	1 time	
Anthracene	Total	8270C	10	µg/L	--	1 time	1 time	
Benzo(a)anthracene	Total	8270C	10	µg/L	--	1 time	1 time	
Benzo(a)pyrene	Total	8270C	10	µg/L	--	1 time	1 time	
Benzo(b)fluoranthene	Total	8270C	10	µg/L	--	1 time	1 time	
Benzo(g,h,i)perylene	Total	8270C	10	µg/L	--	1 time	1 time	
Benzo(k)fluoranthene	Total	8270C	10	µg/L	--	1 time	1 time	
Benzoic acid	Total	8270C	20	µg/L	--	1 time	1 time	
4-Bromophenyl phenyl ether	Total	8270C	10	µg/L	--	1 time	1 time	
Butyl benzyl phthalate	Total	8270C	20	µg/L	--	1 time	1 time	
2-Chloronaphthalene	Total	8270C	10	µg/L	--	1 time	1 time	
4-Chloroaniline	Total	8270C	10	µg/L	--	1 time	1 time	
Carbazole	Total	8270C	20	µg/L	--	1 time	1 time	

Table 5-5. Proposed Analyte List for Water Samples – Continued

Parameter or Analyte	Total / Dissolved (1)	Method (2)	Reporting Limit (2)	Units	Monitor Wells	Pit Lake – Littoral Habitat	Pit Lake – Mid-Lake Water Column	Seeps
Semi-Volatile Organic Compounds (SVOC): *One-time analysis on Pit Lake samples* – Continued								
Chrysene	Total	8270C	10	µg/L	--	1 time	1 time	
bis(2-Chloroethoxy)methane	Total	8270C	10	µg/L	--	1 time	1 time	
bis(2-Chloroethyl)ether	Total	8270C	10	µg/L	--	1 time	1 time	
bis(2-Chloroisopropyl)ether	Total	8270C	10	µg/L	--	1 time	1 time	
4-Chlorophenyl phenyl ether	Total	8270C	10	µg/L	--	1 time	1 time	
2,4-Dintitrotoluene	Total	8270C	10	µg/L	--	1 time	1 time	
2,6-Dinitrotoluene	Total	8270C	10	µg/L	--	1 time	1 time	
3,3′-Dichlorobenzidine	Total	8270C	20	µg/L	--	1 time	1 time	
Dibenzo(a,h)anthracene	Total	8270C	20	µg/L	--	1 time	1 time	
Dibenzofuran	Total	8270C	10	µg/L	--	1 time	1 time	
1,2-Dichlorobenzene	Total	8270C	10	µg/L	--	1 time	1 time	
1,3-Dichlorobenzene	Total	8270C	10	µg/L	--	1 time	1 time	
1,4-Dichlorobenzene	Total	8270C	10	µg/L	--	1 time	1 time	
di-n-Butyl phthalate	Total	8270C	20	µg/L	--	1 time	1 time	
di-n-Octyl phthalate	Total	8270C	20	µg/L	--	1 time	1 time	
Diethyl phthalate	Total	8270C	10	µg/L	--	1 time	1 time	
Dimethyl phthalate	Total	8270C	10	µg/L	--	1 time	1 time	
bis(2-Ethylhexyl)phthalate	Total	8270C	50	µg/L	--	1 time	1 time	
Fluoranthene	Total	8270C	10	µg/L	--	1 time	1 time	
Fluorene	Total	8270C	10	µg/L	--	1 time	1 time	
Hexachlorobenzene	Total	8270C	10	µg/L	--	1 time	1 time	
Hexachlorobutadiene	Total	8270C	10	µg/L	--	1 time	1 time	
Hexachlorocyclopentadiene	Total	8270C	20	µg/L	--	1 time	1 time	
Hexachloroethane	Total	8270C	10	µg/L	--	1 time	1 time	
Indeno(1,2,3-cd)pyrene	Total	8270C	20	µg/L	--	1 time	1 time	
Isophorone	Total	8270C	10	µg/L	--	1 time	1 time	
2-Methylnaphthalene	Total	8270C	10	µg/L	--	1 time	1 time	
2-Nitroaniline	Total	8270C	20	µg/L	--	1 time	1 time	
3-Nitroaniline	Total	8270C	20	µg/L	--	1 time	1 time	
4-Nitroaniline	Total	8270C	20	µg/L	--	1 time	1 time	
Naphthalene	Total	8270C	10	µg/L	--	1 time	1 time	
Nitrobenzene	Total	8270C	20	µg/L	--	1 time	1 time	
N-Nitroso-di-n-propylamine	Total	8270C	10	µg/L	--	1 time	1 time	
N-Nitrosodiphenylamine	Total	8270C	10	µg/L	--	1 time	1 time	

Table 5-5. Proposed Analyte List for Water Samples – Continued

Parameter or Analyte	Total / Dissolved (1)	Method (2)	Reporting Limit (2)	Units	Monitor Wells	Pit Lake – Littoral Habitat	Pit Lake – Mid-Lake Water Column	Seeps
Semi-Volatile Organic Compounds (SVOC): *One-time analysis on Pit Lake samples* - Continued								
Phenanthrene	Total	8270C	10	µg/L	--	1 time	1 time	
Pyrene	Total	8270C	10	µg/L	--	1 time	1 time	
1,2,4-Trichlorobenzene	Total	8270C	10	µg/L	--	1 time	1 time	
Pesticides: *One-time analysis on Pit Lake samples*								
alpha-BHC	Total	8081A	0.10	µg/L	--	1 time	1 time	
beta-BHC	Total	8081A	0.10	µg/L	--	1 time	1 time	
gamma-BHC (Lindane)	Total	8081A	0.10	µg/L	--	1 time	1 time	
delta-BHC	Total	8081A	0.20	µg/L	--	1 time	1 time	
Heptachlor	Total	8081A	0.10	µg/L	--	1 time	1 time	
Aldrin	Total	8081A	0.10	µg/L	--	1 time	1 time	
Heptachlor epoxide	Total	8081A	0.10	µg/L	--	1 time	1 time	
Endosulfan I	Total	8081A	0.10	µg/L	--	1 time	1 time	
Dieldrin	Total	8081A	0.10	µg/L	--	1 time	1 time	
Endrin aldehyde	Total	8081A	0.10	µg/L	--	1 time	1 time	
Endrin	Total	8081A	0.10	µg/L	--	1 time	1 time	
Endosulfan II	Total	8081A	0.10	µg/L	--	1 time	1 time	
4,4′- DDD	Total	8081A	0.10	µg/L	--	1 time	1 time	
Endosulfan sulfate	Total	8081A	0.20	µg/L	--	1 time	1 time	
4,4′-DDT	Total	8081A	0.10	µg/L	--	1 time	1 time	
4,4′-DDE	Total	8081A	0.10	µg/L	--	1 time	1 time	
Methoxychlor	Total	8081A	0.10	µg/L	--	1 time	1 time	
Endrin ketone	Total	8081A	0.10	µg/L	--	1 time	1 time	
alpha-Chlordane	Total	8081A	0.20	µg/L	--	1 time	1 time	
gamma-Chlordane	Total	8081A	0.20	µg/L	--	1 time	1 time	
Toxaphene	Total	8081A	5.0	µg/L	--	1 time	1 time	
Herbicides: *One-time analysis on Pit Lake samples*								
2,4,5-T	Total	8151A	1.0	µg/L	--	1 time	1 time	
2,4-D	Total	8151A	1.0	µg/L	--	1 time	1 time	
2,4-DB	Total	8151A	1.0	µg/L	--	1 time	1 time	
Dalapon	Total	8151A	5.0	µg/L	--	1 time	1 time	
Dichloroprop	Total	8151A	1.0	µg/L	--	1 time	1 time	
Dicamba	Total	8151A	1.0	µg/L	--	1 time	1 time	
Dinoseb	Total	8151A	1.0	µg/L	--	1 time	1 time	

Table 5-5. Proposed Analyte List for Water Samples – Continued								
Parameter or Analyte	**Total / Dissolved (1)**	**Method (2)**	**Reporting Limit (2)**	**Units**	**Monitor Wells**	**Pit Lake – Littoral Habitat**	**Pit Lake – Mid-Lake Water Column**	**Seeps**
Herbicides: *One-time analysis on Pit Lake samples* – Continued								
MCPA	Total	8151A	300	µg/L	--	1 time	1 time	
MCPP	Total	8151A	300	µg/L	--	1 time	1 time	
Silvex	Total	8151A	1.0	µg/L	--	1 time	1 time	
PCBs: *One-time analysis on Pit Lake samples*								
Aroclor-1016	Total	8082	1.0	µg/L	--	1 time	1 time	
Aroclor-1221	Total	8082	1.0	µg/L	--	1 time	1 time	
Aroclor-1232	Total	8082	1.0	µg/L	--	1 time	1 time	
Aroclor-1242	Total	8082	1.0	µg/L	--	1 time	1 time	
Aroclor-1248	Total	8082	1.0	µg/L	--	1 time	1 time	
Aroclor-1254	Total	8082	1.0	µg/L	--	1 time	1 time	
Aroclor-1260	Total	8082	1.0	µg/L	--	1 time	1 time	

Notes: (1) Dissolved constituents will be field filtered with a disposable 0.45 micron filter.
(2) EPA laboratory analytical methods and reporting limits are consistent with those provided in the Project QAPP (Revision 2, August 21, 2007); alternative analytical methods identified in the QAPP may also be used.

5.1.7 Collection of Biological Data and Habitat Survey Information and SLERA

Appendix B of this Pit Lake RI Work Plan describes the FSAP aspect of the SLERA Work Plan, and the collection and analysis of ecological information from a proposed habitat survey. Vegetated areas within the open pit occur up to 75 feet above the current lake level in areas associated with highwall seeps (Appendix E), and may provide shelter or food to wildlife species. In addition, the pit lake may provide habitat for birds, fish, invertebrates and aquatic plants. The SLERA Work Plan will be performed to characterize the habitats and receptors that may be present within the open pit, and to determine whether potential exposure to mine-related chemicals associated with the Pit Lake OU warrants further evaluation in a baseline ecological risk assessment (“BERA”). The SLERA will be based, in part, on ecological investigations of upland and aquatic habitats associated with the Pit Lake OU (see Appendix B-1) including:

- Upland areas assessments of plant and wildlife habitat;
- Aquatic bird habitat assessment; and

- Aquatic areas assessment of limnological conditions, the aquatic macroinvertebrate community, and a survey of fish presence/absence.

The results of the ecological characterization will be synthesized with information collected during the remedial investigation for pit lake media (e.g., surface water, seeps, soils and sediment) and biota to estimate exposure to aquatic and upland receptors of concern, as described in the SLERA Work Plan (Appendix B-2). The SLERA Work Plan follows EPA guidance to provide estimates of risks to potentially exposed aquatic and upland plants and animals; the methodology is designed to avoid underestimation of risks to provide a conservative basis for evaluating the need for additional site-specific risk assessment, remedial action, and options for future land use. The SLERA can be used to refine the conceptual site model for the Pit Lake OU and, if needed, support the elements of the Problem Formulation Step of a BERA.

5.1.8 Compilation of Potential Human Health Risk Factors.

The primary objective of the HHRA is to evaluate potential adverse health effects attributable to exposure to site-related chemicals under current and future conditions. The risk assessment will provide conservative estimates of risks using methodology and EPA guidance designed to avoid underestimation of risks (this approach will likely overestimate risks to provide a conservative basis for evaluating the need for any additional remedial action and options for future land use). Data collected pursuant to this Pit Lake RI Work Plan will be used to: 1) refine the conceptual site model through identifying exposure media and assessing complete exposure routes for human populations; and 2) evaluate human health risks associated with pit lake media (e.g., surface water, seeps, soils and sediment) and biota.

5.1.9 Collection and Analysis of Pit Highwall Geotechnical Data

The evaluation of pit highwall stability, including stability of slopes above the North and South pit lake access ramps, will include a site reconnaissance, collection and compilation of available information, preliminary evaluation of available data, and evaluation of geotechnical conditions. The objectives of the site reconnaissance and data collection activities include the following:

- Collect and compile available geologic, geotechnical, and hydrogeologic data;
- Evaluate reliability of current geological and hydrogeological models based on data review and site reconnaissance;
- Evaluate slope performance and impacts of geology and time on slope performance, and;
- Evaluate potential groundwater impacts on slope stability and adequacy of current understanding of groundwater conditions.

Site Reconnaissance and Collection and Review of Data and Geotechnical Model

An inspection of the current pit slopes will provide the basis for the evaluation of future performance. ARC anticipates that the most reliable stability evaluations will be based in part on data from site performance and history. Lithologic and alteration units, and major structural elements of the pit will be evaluated in the context of rock strength and both small- and large-scale bench and slope stability characteristics.

Slope Stability Evaluations

Based on access and health and safety considerations, and the results of the first step activities, geotechnical mapping may be performed to field check and supplement existing data. Fracture orientation data derived from field observations are important to define areas of the pit with similar structural characteristics, and to assess correlations between major structural elements and the small-scale fractures.

The analysis of results obtained compiling historic and current geotechnical field observations will be compared to Seegmiller (1979) for calibration to facilitate classification of geographic areas within the Pit Lake OU for staff health and safety protection purposes. A geographic map depiction defining 3 to 5 levels of activity exclusions based on absence or severity of potential health and safety threats identified in the observed geotechnical conditions in the Pit Lake OU. This map will be used in future field activity planning.

5.2 Phase 2 Activities

The second phase of the investigation will include the sub-phases listed below. ARC anticipates that a nominal three year period for Phase 2 activities will be sufficient to confirm whether or not the pit lake will reach, or closely approach, hydraulic "steady-state" conditions in the time frame indicated in Figure 3-11. The three-year period, which should coincide with the years 2010 through 2013, will also provide sufficient time for the completion of the human health and ecological risk assessments. Phase 2 activities include:

- Phase 2-1 Preparation of a Data Summary Report for the Phase 1 investigation, and a Pit Lake RI Work Plan Addendum that addresses additional monitoring proposed for the second phase of the investigation.
- Phase 2-2 Continuation of selected Phase 1 monitoring activities including: 1) measurements of groundwater elevations and pit lake levels; 2) collection of groundwater samples from selected pit area monitor wells and laboratory analyses of selected constituents; 3) collection of pit lake water samples from selected depths and/or areas; and 4) meteorological conditions. Annual monitoring reports for the collected data will be prepared and submitted to EPA.
- Phase 2-3 Potential implementation of additional field investigations and/or monitoring not anticipated in this Pit Lake RI Work Plan resulting from the information presented in the Data Summary Report.

5.2.1 Data Summary Report

Phase 1 characterization and monitoring activities will be compiled and integrated into a Data Summary Report, which will provide an interpretation of the various data sets resulting from the remedial investigations. Predictive analyses and/or modeling of pit lake "steady-state" conditions including hydraulic, limnological and geochemical parameters will also be included in the report. ARC does not anticipate an extensive statistical evaluation of data collected as part of Phase 1 investigations due to the limited (1-year) period of data collection. The goal of the statistical analysis will be to support the final HHRA and SLERA, and the selection of a remedial alternative as part of the subsequent feasibility study, for the Pit Lake OU. The Data Summary Report will present the results of the remedial investigations described in Section 5.1, and include the following major elements:

- Assessment and analysis of the pit lake water balance components based on analytical or numerical modeling, with an emphasis on hydrogeologic and meteorological data;
- Characterization of pit lake limnology and hydrodynamic behavior, based on analytical or numerical modeling, and sediment physical and chemical characteristics;
- Characterization of pit lake water quality, including a comparison of analytical results to groundwater and surface water chemical, to predict "steady-state" water quality using analytical or numerical modeling tools;
- Characterization of the highwall stability of the pit.

Approximately six months after the submittal of the Data Summary Report, ARC will submit the SLERA and HHRA reports to address the following:

- Characterization of the biological properties of pit lake sediments, and potential sediment influence on pit lake biota, and pit lake biological productivity and nutrient pathways.
- Assessment of the nature and composition of aquatic plant and animal species, and their potential uptake by higher semi-aquatic vertebrates in conjunction with the vegetative and wildlife habitat associated with riparian and upland sections of the pit lake shore and proximal highwall areas.
- Potential human use of the lake and/or pit lake water, and associated potential health risks including effects on tribal lifeways.

The SLERA will rely heavily on the results of the ecological investigations described in Appendix B-1. In addition to the interpretations and predictive analyses, the following information from the field activities and laboratory analyses resulting from Phase 1 investigations will be presented in the Data Summary Report:

- A description of sampling procedures, locations and field conditions including relevant photographs;
- Boring logs and monitor well construction diagrams;
- Meteorological and limnological data sets;
- Groundwater and pit lake elevation data sets, and water quality field parameter measurements;
- Laboratory data sheets and data validation results, and a summary of any QA/QC issues for water quality and sediment analyses;

- Geotechnical data including monitoring results; and
- Pit lake biological data (either attached or submitted separately).

In conjunction with the preparation of the Data Summary Report, ARC will prepare a Pit Lake RI Work Plan Addendum to address any data gaps or data adequacy issues mutually agreed upon by ARC and EPA, and recommend additional monitoring activities for the nominal three-year Phase 2 period. The following describes the major components of the Data Summary Report:

Evaluation of Pit Area Hydrogeology and Groundwater and Pit Lake Elevation Data

Geologic information and groundwater elevation data will be compiled to evaluate hydrogeologic conditions in the area of the open pit (i.e., the area within and immediately adjacent to the hydraulic capture area of the pit lake relative to the bedrock flow system, and the alluvial sources of groundwater recharge into the pit). These data will be used to develop maps, cross sections and other figures that illustrate groundwater conditions in the pit area that integrate local topography, geology and groundwater flow data. The influence of structural geology on the relationship between groundwater and pit lake elevations will also be discussed.

Water level monitoring data obtained from groundwater monitor wells and the pit lake will be used to develop groundwater potentiometric surface maps and hydrologic cross sections, similar to those provided as Figures 3-8 and 3-9. The maps and cross sections will illustrate the vertical and horizontal components of groundwater flow, and seasonal or temporal changes in groundwater elevations or hydraulic gradients, and hydraulic relationships between the alluvial and bedrock groundwater flow systems and the pit lake.

Pit Lake Runoff Calculations

Conceptually, the runoff contribution to the pit lake water balance will be a percentage of the total annual average precipitation that falls on the hydrologoic capture area of the pit. The remainder of the precipitation rate will be divided into percolation and potential sub-flow into the pit lake, and evaporation (the percentage of infiltrated precipitation will be reduced by the moisture storage capacity of the alluvial portion of the exposed highwalls). Overall, this component of the pit lake water balance is conceptualized to be very small in comparison to the groundwater inflow contribution and losses due to evaporation.

Runoff of incident precipitation within the hydrologoic capture area of the pit lake will be calculated using the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) software, developed by the U. S. Army Corps of Engineers, which is designed to simulate the precipitation-runoff processes of watershed systems. This software is widely used in the mining industry to calculate surface water runoff around mine sites, including open pits. The pit capture area will be segmented into discrete sub-areas for the runoff calculations based on geology, inter-bench slope angles and perimeter topography. Each sub-area runoff model will be based on the specific 'watershed' characteristics and, to some degree, engineering judgment.

Meteorological and Limnological Analysis

Meteorological station data will be used to establish transfer functions for predicting the influence of lake high walls on local meteorological conditions adjacent to the lake. The geometry of the open pit is conceptualized to attenuate wind velocity, and may also affect air temperature and relative humidity at the lake surface. Transfer functions are simply a mechanism of correlating two or more variables to each other (in this case, wind speed, surface temperature, and relative humidity at the surface and outside the lake). A similar procedure has been applied to a detailed meteorological and hydrologic study of three pit lakes in British Columbia (Hamblin et al., 1999). A transfer function to correlate surface air and water temperature during periods of lake stratification will also be constructed for use in modeling longer term behavior of the pit lake water column stability, as discussed below.

Precipitation-Evaporation Calculations

Data from the shoreline meteorological station, rain gauge and midlake surface thermistor will be used to calculate surface precipitation-evaporation values. Using water temperature, air temperature, and relative humidity data, evaporation will be determined from simple Dalton ratios (e.g., Dingman, 1993):

$$E = K_E U_W (e_s - e_a)$$

where E is evaporation rate in cm/day, K_E is an empirical coefficient, U_w is wind speed in cm/s and e_s and e_a are vapor pressures in millibars of the evaporating surface and overlying air, respectively. An empirical relationship between K_E and lake area, A_L, was established by Harbeck (1962):

$$K_E = (.0000168)A_L^{-0.05}$$

The saturation and air vapor pressures will be calculated using the following relationships (Dingman, 1993):

$$e_s = e_{sat}(T) = 6.11\exp(17.3T/(T+237.3))$$

and

$$e_a = R_H e_{sat}(T_a)$$

where T is surface water temperature (^oC), R_H is relative humidity (expressed as a fraction), and T_a is air temperature (^oC). This relatively simple approach for determining evaporation (E) and precipitation (P as determined from rain gauge data) will be applied using meteorological and thermistor data for an entire season. A summary of the variable used in these relationships is provided below:

- A_L = Lake area
- T = Surface water temperature from thermistor
- Ta = Surface air temperature from met station
- R_H = Relative humidity from met station
- U_w = Data from the met station deployed adjacent to the lake surface

Water Column Stability Analysis

Data from the meteorological station, Hydrolab probe, and thermistor will provide the inputs for an assessment of seasonal water column stability in the pit lake. This assessment will provide the basis for a predictive numerical model of the long term water stability of the lake. The dimensionless Wedderburn number, W, reflects the balance between buoyancy that tends to stabilize a water column and wind shear that will mix it (e.g., Imberger and Patterson, 1990):

$$W = g'H^2/u^{*2}L$$

where g' is "reduced gravity" (the gravitational constant times ($\Delta\rho/\rho$) measured across the thermocline), H is the thickness of the thermocline, and L is the length of the lake at the thermocline depth. If the Wedderburn number is > 1, the water column is considered stable. The parameter u*, the shear velocity, is defined as:

$$U^{*2} = (\rho a/\rho o)C_D U_W^2$$

where ρ_a/ρ_o is the density ratio of air to water, C_D is a drag coefficient, and U_w is surface wind speed. The appropriate constants and data necessary to compute the Wedderburn number are summarized below:

- $\Delta\rho$ = Density equation of state calculations (e.g., McCutcheon et al., 1993) above and below the thermocline using data from the multi-sensor probe;
- H = Data on thermocline depth from the multi-sensor probe;
- L = Average length of the lake thermocline based on lake bathymetry and multi-sensor data;
- ρ_a/ρ_o = Assumed to be a constant .00123 (although air density is a function of temperature and water density is a function of temperature and dissolved solids, the range of this variable is small relative to other components of the Wedderburn number)
- C_D = Assumed to be a constant .0012 for wind speed (U_a) < 11 m/s; CD = .00049 + .0000*U_a for wind speeds up to 25 m/s (this relationship is from Pond and Pickard [1983], and found to applicable to a wide range of surface water settings); and
- U_w = Wind speed from the meteorological station deployed adjacent to the lake lake.

Calculation of the Wedderburn number over a complete season will: 1) allow evaluation of the general applicability of this parameter for predicting lake stability; and 2) provide input for numerical models to study lake stability under a variety of climate scenarios. In addition, the

Wedderburn calculations will be able to test the potential effects of increasing atmospheric temperatures on pit lake limnology and, potentially, long-term water quality. Predicted changes in meteorological variables will be taken from recent estimates of climate change in the western Great Basin (e.g., Regonda et al., 2005; Christensen, et al., 2007), and converted to surface water temperatures using the transfer function previously discussed.

Hydrodynamic Modeling

Understanding the long-term stability of the lake water column will be evaluated with CE-QUAL-W2, a two-dimensional hydrodynamic model developed by the U. S. Army Corps of Engineers and widely used to model the stability and geochemistry of lakes and reservoirs (e.g. Imberger and Patterson, 1990; Cole and Wells 2002). CE-QUAL-W2 can also evaluate two-dimensional water quality conditions, and simulate the following parameters, not all of which may be applicable to the Yerington Pit Lake:

- water surface elevations
- horizontal and vertical velocities of water masses;
- energy budget;
- ice cover;
- variable density;
- temperatures;
- precipitation;
- tributary inflows;
- evaporation;
- algae effects, and
- over 60 chemical constituents, including dissolved oxygen.

Hydrodynamic modeling objectives include: 1) the extrapolation of limnological conditions observed during Phase 1 investigations to the hydraulic "steady-state" condition; 2) the identification of any critical physical or chemical data gaps that may be required to predict "steady-state" geochemical conditions in the pit lake; and 3) the evaluation of the suitability of the much simpler Wedderburn calculations (e.g., Stevens and Lawrence, 1998; Hamblin et al., 1999) to address the issue of long-term pit water quality. Boundary conditions modeled by CE-QUAL-W2 include inflows and outflows, evaporation and precipitation. CE-QUAL-W2 requires a number of kinetic input parameters including suspended solids settling rates, algal growth, respiration and mortality rates, organic matter decay and settling rates, sediment oxygen demand, and nitrogen, phosphorus and iron transformation rates.

Pit Lake Water Balance Calculations

ARC proposes to use an analytical solution to evaluate the pit lake water balance, using inputs from the previously described data sets. The inflow components of the water balance are direct precipitation, runoff, interflow and groundwater recharge. The outflow components are evaporation and estimated flows from the alluvium on the west side of the pit. This type of analytical solution has been used for other pit lake water balance calculations, and has proven successful in simulating historic pit refilling rates and predicting future pit lake equilibrium levels. The water balance equation for the analytical solution is presented below:

$$Vt = Vp + (P + R + I + G - [E + D])(t - tp)$$

where:

Vt = volume of water in the pit at time t,

Vp = volume of water in the pit at the end of the previous time step,

P = precipitation volume per unit time,

R = runoff volume per unit time,

I = interflow volume per unit time,

G = groundwater inflow per unit time,

E = evaporation volume per unit time,

D = discharge volume of pit water into the alluvium per unit time, and

tp = time at the end of previous time step.

Once calibrated for data accumulated through 2009, the analytical solution will be used to predict hydraulic conditions through 2015. The additional monitoring activities described in Section 5.2.2 will provide the data for additional calibration and sensitivity analysis for the input parameters for the water balance equation. Results of the calibrated pit lake water balance will be used to support the estimate of pit lake water quality under "steady-state" conditions.

Estimation of Steady-State Pit Lake Water Quality

A number of analytical and numerical methods can be used to predict pit lake water quality under "steady-state" conditions. ARC anticipates that some combination of predictive tools would be used for the Yerington Pit Lake analysis. A large degree of confidence in the predictive analysis can be achieved by incorporating the type of pit lake water quality data proposed to be collected pursuant to this Pit Lake RI Work Plan. For example, an analytical solution as proposed by Lewis (1999; presented in full in Appendix C) can be used to conservatively estimate pit lake water quality with some focused refinement using numerical geochemical modeling tools such as PHREEQC (Parkhurst, 1995), MINTEQA2 (Allison et. al., 1993) and NETPATH (Plummer et. al., 1994) for selected constituents (e.g., copper, selenium).

During the early stages of pit refilling, pit inflow components are at a maximum (primarily ground water inflow) and evaporation is at a minimum (minimal lake surface area), and the pit water composition closely reflects the inflow composition. During this phase, groundwater chemical concentrations are commonly modified by interactions with variably oxidized wallrock, including oxidized sulfide materials that typically release acid and metals. As pit filling continues, the inflow gradually decreases and evaporation increases, resulting in a concentration of chemicals in the pit lake. Upon the completion of pit refilling, and achievement of hydraulic "steady-state" conditions, evapoconcentration and precipitation processes in the epilimnion, and seasonal turnover of the lake become more important influences on pit water quality, as described in Section 3.0. Lewis (1999) published the following steady-state mass-balance equation for a conservative chemical constituent in a pit lake (e.g., chemicals that would not react to form precipitates and be sequestered in pit lake sediments):

$$Q_{in}C_{in} = Q_{out}C_{out} \qquad (1)$$

where,

Q_{in} is the equilibrium pit inflow rate,

Q_{out} is the equilibrium pit out-flow rate,

C_{in} is the inflow concentration and

C_{out} is the outflow concentration.

The outflow components on the right-hand side of Eq. (1) can be expanded as:

$$Q_{out}C_{out} = Q_{evt}C_{evt} + Q_{gsout}C_{gsout} \qquad (2)$$

where,

Q_{evt} is the evaporation rate

C_{evt} is the evaporation concentration,

Q_{gsout} is the combined ground water/surface-water outflow rate and,

C_{goust} is the ground water/surface-water outflow concentration (groundwater and surface-water outflow concentrations are assumed to be equal under fully mixed conditions).

Because C_{evt} is zero, Eq. (2) can be reduced to:

$$Q_{out}C_{out} = Q_{gsout}C_{gsout} \qquad (3)$$

The steady-state flow balance is:

$$Q_{gsout} = Q_{in} - Q_{evt} \qquad (4)$$

Further, the pit lake concentration (C_{pit}) is equal to the ground water/surface-water outflow concentration at "steady-state" conditions or

$$C_{pit\ =}\ C_{gsou} \qquad (5)$$

Substitution of Equations (3), (4) and 5 into Equation (1), and rearranging these gives the following expression for steady-state concentration

$$\frac{C_{pit}}{Q_{in}} = \frac{Q_{in}}{Q_{in} - Q_{evt}} \qquad (6)$$

where,

Q_{in} represents the flow-weighted average concentration of all inflow components or

$$Q_{in} = \frac{Q_{gwin}C_{gwin} + Q_{swin}\,C_{swin} + Q_{run}C_{run} + Q_{precip}C_{precip}}{Q_{in}} \qquad (7)$$

The subscripts *win*, *swin*, *run* and *precip* represent ground water, surface-water, runoff and direct precipitation flows and concentrations, respectively; and Q_{in} represents the total pit-inflow rate of the sum of the four pit inflow components. Equation (6) simply states that the steady-state concentration is dependent only on the inflow concentration, inflow rate and evaporation rate. Further, the relative concentration (ratio of pit concentration to in-flow concentration) is a function of only the inflow and evaporation rates. Equation (6) also indicates that the concentration of constituent will increase without limit as Q_{gsout} approaches zero (i.e., a closed pit or sink) or when evaporation exactly equals inflow (in practice, the concentration would increase until chemical saturation and precipitation occurs, and the dissolved concentration would then remain constant). These relationships developed by Lewis (1999) can be used as an initial analytical tool for evaluating pit lake water quality under "steady-state" conditions.

Pit Highwall Slope Stability Assessment

The results of the data collection and compilation, site investigation, geotechnical model development, and engineering analyses will be documented in an engineering report attached to the Data Summary Report. The engineering report will include a description of all assumptions and models used in the analysis and recommendations, such that a third-party reviewer would be able to independently reproduce the results. The engineering report will provide predictions of slope stability, and the potential for rapid or catastrophic slope failures, based on the Phase 1 site characterization activities, including the degree of uncertainty associated with the predictions. Potential geotechnical risks, and methods for mitigating those risks by regrading, drainage enhancements and/or monitoring, will also be discussed.

5.2.2 Supplemental Monitoring

The following general concepts for supplemental Phase 2 monitoring of groundwater and pit lake conditions would be presented in greater detail in the Pit Lake RI Work Plan Addendum. During the nominal three-year Phase 2 investigation period, ARC may request modifications to the data sets being collected, and submit rationale to EPA for any requested modifications.

Groundwater Elevations and Pit Lake Levels

ARC anticipates that the groundwater elevation and pit lake level data collected during the initial two-year characterization and monitoring program described in Section 5.1 would continue without modification for the nominal three-year Phase 2 period.

Groundwater and Pit Lake Water Quality

Groundwater quality sampling for the initial two-year characterization and monitoring period, described in Section 5.1, would continue with proposed modifications to the monitoring frequency and analyte list, to be presented in the Pit Lake RI Work Plan Addendum. Monitoring of groundwater quality in pit area wells is anticipated to be consistent with modifications to the Draft Site-Wide Groundwater Monitoring Plan, although specific differences could be proposed.

Highwall Seeps

To the extent possible, based on observed health and safety issues associated with access, monthly flow rates from the east and west highwall spring discharge monitoring locations (safe access, if any, to the west seep would be established during Phase 1 investigations) will continue to be monitored. The need for supplemental water quality monitoring, or rationale for eliminating water quality monitoring, will be documented in the Pit Lake RI Work Plan Addendum based on the information presented in the Data Summary Report.

Meteorological and Limnological Conditions

The meteorological data proposed for collection during the initial two-year characterization and monitoring program described in Section 5.1 would continue for the nominal three-year Phase 2 period.

Geotechnical Parameters for Highwall Stability

The geotechnical data proposed for collection during the initial two-year characterization and monitoring program, to be developed as part of the Phase 1 remedial investigations, are likely to continue during the nominal three-year Phase 2 period. However, specific details of such monitoring activities would be presented in the Pit Lake RI Work Plan Addendum based on information presented in the Data Summary Report.

5.2.3 Supplemental Investigations

Any supplemental investigations resulting from the information provided in the Data Summary Report would be addressed in the Pit Lake RI Work Plan Addendum.

5.3 Phase 3 Activities

Phase 3 activities include the preparation of a Remedial Investigation (RI) Report and, as required, a baseline ecological risk assessment (BERA). The BERA will either be attached as an appendix to the Remedial Investigation Report, or submitted as a separate report. A final version of the HHRA may also be submitted along with the RI and BERA Reports, or submitted in conjunction with a Site-Wide HHRA Report. ARC anticipates that the RI Report will include: 1) a summary of all pit lake investigations performed to date, including monitoring conducted pursuant to the Pit Lake RI Work Plan Addendum; 2) updated predictive analyses (i.e., analytical solutions and/or modeling) of pit lake hydraulic, limnological, geochemical and geotechnical conditions including a description of assumptions and revised input parameters that may differ from what was presented in the Phase 1 Data Summary Report; 3) statistical analysis of appropriate collected data (i.e., pit lake water quality data) and 4) recommendations for continued or additional monitoring that would support the feasibility study for the Pit Lake OU.

The need for additional pit lake water quality monitoring data will likely be driven by the robustness of the available data set for the statistical analysis of the collected geochemical data.

5.3.1 Remedial Investigation Report

The Pit Lake RI report will summarize all investigations conducted through the approximate five-year remedial period described in Sections 5.1 and 5.2, and include the information previously provided in the Data Summary Report for Phase 1 activities and subsequent annual monitoring reports. All supplemental data will be compiled and summarized in tables, figures and data graphics similar to those presented in this Pit Lake RI Work Plan, which will also provide a more complete statistical interpretation of the collected data than anticipated for the Data Summary Report. The volume of data, and the need to integrate the wide range of technical disciplines associated with the pit lake (e.g., hydrogeology, meteorology, limnology, geochemistry and biology), will result in a comprehensive RI Report that will provide the framework for a focused feasibility study.

In addition, groundwater flow and geochemical conditions associated with the pit lake will need to be integrated with similar data to be collected pursuant to the Site-wide Groundwater RI Work Plan (i.e., data from one work plan may result in scope changes to the other, particularly in the southern portion of the Site). Given these considerations, ARC and EPA should develop a strategy to allow for these comprehensive and complex remedial investigations, and associated RI Reports, to progress and culminate in a cohesive manner.

5.3.2 Additional Supplemental Monitoring

After completion of the RI Report, ARC and EPA may agree to additional supplemental monitoring focused on the same data previously discussed, and listed below:

- Groundwater elevations and pit lake levels;
- Groundwater and pit lake water quality;
- Highwall seeps; and
- Meteorological and limnological conditions.

SECTION 6.0

QUALITY ASSURANCE PLAN

Investigations will be conducted pursuant to the revised site-wide project QAPP (ESI and Brown and Caldwell, 2007), which incorporates the following: standard operating procedures, equipment calibration and maintenance, field and laboratory QC samples, data validation, corrective action, and data completeness. The goal of the quality assurance program is to produce data sets that are consistent, have little bias, high precision and that meet the project goals. QA procedures will be implemented on field data collection and sampling as well as laboratory analytical methods. A review of data results will be completed by a QA oversight contractor in order to determine whether the project data goals have been met, and if any data must be qualified or rejected due to data quality issues. The QA/QC issues include:

- Sample identification, handling, and transport;
- Equipment decontamination;
- The use of quality control samples such as blanks and duplicates;
- Field documentation; and
- Data review.

6.1 Sample Identification

Each sample will be placed in clean, unused sample container provided by the laboratories and will be labeled with the sample identification number. The labels will be filled out with a permanent marker and will include the following information:

- Sample identification
- Date and time of sample collection
- Sampler's initials
- Analyses requested
- Preservation method (if required)
- Project name

Each sample will be tracked according to its unique sample field identification number assigned when the sample is collected and recorded clearly in the field notebook. The field identification number will include:

- Operable Unit Prefix (e.g., Yerington Pit Lake = YPL)
- Location or Sample Type Descriptor (e.g., Lake Water = LW, Lake Bottom Sediment = LBSed, Walker River Seep = WRSeep)
- Sample location number (e.g., 01)
- Sample interval or depth(e.g., -1, -5, -10)

For example, the sample of Pit Lake water collected from the 20 feet below the surface at location number 1 would be labeled YPL-LW-01-20. All final sample locations and designations will be presented in a Data Summary Report. Upon collection, samples will be placed in a cooler and chain of custody, sample preservation and shipping procedures will be followed as defined in SOP-01 “Environmental Sample Handling” and SOP-02 “Sample Preservation” (Appendix H).

6.2 Handling and Preservation

All collected samples shall be preserved according to the requirements of the analytical method and the QAPP and shall be analyzed within the designated hold time, which varies for different analytes. Table 6-1 summarizes the required sample volume, container, preservative and holding time required for each analytical method required in this Work Plan. Variations in sample volume may be requested by the project laboratories. Immediately following collection, samples will be placed into an insulated cooler chilled with ice if temperature preservation is required. The samples will be transported to the analytical laboratory via overnight mail or ground delivery depending on sample hold times.

Table 6-1. Sample Containers, Preservation, and Holding Times

Parameter	EPA Method(s)	Suggested Volume[1]	Container	Preservative[a]	Holding Time from Collection
Aqueous Samples					
Alkalinity	2320B	200 mL	P or G	≤6°C	14 days
Chloride, Fluoride, Total Nitrate/Nitrite, and Sulfate	300.0	200 mL	P or G	≤6°C	28 days
Nitrate, Nitrite	300.0	200 mL	P or G	≤6°C	48 hours
Phosphorus (total)	365.3	200 mL	P or G	≤6°C, H_2SO_4 to pH<2	28 days
pH	150.1, 4500B/H	200 mL	P or G	≤6°C	24 hours
TDS	160.1, 2540C	200 mL	P or G	≤6°C	7 days
TOC	5310C	200 mL	G/T	≤6°C, H_3PO_4 to pH<2	28 days
Metals (total)	6010B, 200.7, 6020, 200.8	500 mL	P	HNO_3 to pH<2	6 months
Metals (dissolved)	6010B, 200.7, 6020, 200.8	500 mL	P	Field Filtered and then HNO_3 to pH<2	6 months
Mercury	7470A, 245.1	200 mL	P	HNO_3 to pH<2	28 days
Radiochemicals	900.0, 903.0, 904.0, 907.0	4 L	P	HNO_3 to pH<2	6 months
TPH Diesel (C12-C23)	8015B	2 x 1 L	G/T	≤6°C, HCl to pH<2[d]	7/40 days[c]
TPH Motor Oil (C23-C40)	8015B	2 x 1 L	G/T	≤6°C, HCl to pH<2[d]	7/40 days[c]
TPH Gasoline (C4-C12)	8015B	3 x 40 mL	G/T	≤6°C, HCl to pH<2, no headspace[b]	14 days
Volatile Organics	8260B	3 x 40 mL	G/T	≤6°C, HCl to pH<2, no headspace[b]	14 days
Semivolatile Organics	8270C	2 x 1 L	AG	≤6°C	7/40 days[c]
Pesticides	8081A	2 x 1 L	AG	≤6°	7/40 days[c]
Herbicides	8151A	2 x 1 L	AG	≤6°	7/40 days[c]
PCBs	8082	2 x 1 L	AG	≤6°C	7/40 days[c]
Soil/Sediment					
Metals	6010B, and 6020	50 g	WM	None	6 months
Mercury	7471A	50 g	WM	≤6°C	28 days
Radionucludes	901.1, 903.0, 904.0	750 g	WM	None	6 months
Total Solids	160.3, 2540G	50 g	WM	≤6°C	7 days
TPH Diesel (C12-C23)	8015B	100 g	WM	≤6°C	14/40 days[b]
TPH Motor Oil (C23-C40)	8015B	100 g	WM	≤6°C	14/40 days[b]
TPH Gasoline (C4-C12)	5035-8015B	5 g/ container	3 – En Core® or Tared vials	≤6°C	48 hours/ 14 days[c,d]
Volatile Organics	5035-8260B	5 g/ container	3 – En Core® or Tared vials	≤6°C	48 hours/ 14 days[c,d]
Semivolatile Organic	8270C	100 g	WM	≤6°C	14/40 days[b]
Pesticides	8081A	100 g	WM	≤6°C	14/40 days[b]
Herbicides	8151A	100 g	WM	≤6°C	14/40 days[b]
PCB	8082	100 g	WM	≤6°C	14/40 days[b]

Notes:

[1] Extra volume must be provided for matrix QC samples (MS, MSD, and/or laboratory duplicate samples.

[a] Preservation should be done immediately upon sample collection (within 15 minutes).

[b] Extract sample within 14 days. Analyze extract within 40 days after extraction.

[c] If collecting En Core® samples, samples must be preserved with methanol and ≤6°C, sodium bisulfate and ≤6°C, or reagent water and ≤-10°C within 48 hours of collection and analyzed within 14 days of collection.
En Core® samples can also be stored ≤-10°C and analyzed within 7 days of collection.

[d] If collecting samples in En Core® samplers, an additional aliquot sample must be collected and submitted to the laboratory for percent solids analysis.

P = plastic, G = glass, AG = amber glass, T = Teflon lined cap, WM = Wide-mouth glass jar with Teflon®-lined cap.

The following sample preservation methods would be followed for collected groundwater samples:

- If the sample is to be analyzed for dissolved metals, filter sample through a 0.45-micron filter using an in-line filter immediately after sample collection. After filtering, add nitric acid to the sample to achieve a pH of less than 2.
- If the sample is to be analyzed for total metals, do not filter. Add nitric acid to the collected sample until the pH is less than 2.
- If the sample is to be analyzed for nitrate, do not filter. Add sulfuric acid to the collected sample to achieve a pH of less than 2.
- Check the pH by pouring a small amount of sample into the bottle cap and checking the pH with pH paper.
- Discard the liquid in the cap after checking the pH.
- Replace the cap, place the sample container in a sealed zip-loc plastic bag, and cool the sample to 4°C by immediately placing it in an insulated chest with containerized ice.
- Indicate on the sample label what the requested analysis is (e.g., dissolved or total).
- Observe the maximum holding times and storage conditions for all collected water samples.

Sample containers, preservation methods, and filtering methods are described below.

6.3 Equipment Decontamination

As needed, with the exception of disposable equipment, all sample collection equipment will be decontaminated between each sample. SOP-05 “Equipment Decontamination” in Appendix H provides detailed procedures on project implementation of equipment decontamination. In general, sampling equipment will be hand-washed with a solution of tap water and Alconox detergent, rinsed with distilled or tap water, rinsed with a weak nitric acid solution, and a final rinse in clean distilled water. After use, gloves and other disposable PPE will be containerized and handled as investigation derived waste.

6.4 Quality Control Samples

The QA objectives for the sample-handling portion of the field activities are to verify that sample collection, packaging and shipping are not introducing variables into the sampling chain that could provide any basis to question the validity of the analytical results. In order to fulfill these QA objectives, QC samples will be prepared and submitted. If the analysis of the QC sample indicates that variables were introduced into the sampling chain, then the samples shipped with the questionable QC sample will be evaluated for the possibility of cross-contamination in the field or breach of laboratory QC. All blanks and duplicate samples will be labeled in the same manner as regular samples, with no indication that they are QC samples and will be submitted for the complete suite of analytes as the normal samples they are being submitted with.

Field Duplicates – Field duplicates are used to check for sampling and analytical error, reproducibility, and homogeneity. Duplicate samples will be collected at a frequency of one per every 20 investigation samples and each sample from a duplicate set will have a unique sample identification. Duplicate samples will be collected by gathering twice the sample volume, blending to homogenize the sample if no VOC are being analyzed, and splitting the blended sample into separate containers for the original and the duplicate samples.

Equipment Rinsate Blanks – Analyses of equipment rinsate blanks are used to assess the efficiency of field equipment decontamination procedures in preventing cross-contamination between samples. Equipment rinsate blanks will be collected at a frequency of one per 20 samples, and at least once each day samples are collected, by pouring laboratory grade de-ionized water over the reusable sampling equipment and collecting in a clean container.

Field Blanks – Field blanks are used to assess possible contamination of samples during the sample collection process due to airborne contaminants. Field blanks are collected by pouring laboratory grade dionized water into a sample container under the same field conditions as the original sample was collected. They will be collected at a frequency of one per 20 samples.

Matrix Spike/Matrix Spike Duplicate (MS/MSD) Samples – MS/MSD samples are investigative samples to which known amounts of analytes are added in the lab before analysis. The recoveries for spiked compounds can be used to assess how accurate the analytical method is for the site-specific sample matrix. MS/MSD samples for water typically require submitting twice the sample volume by filling two sets of sample containers in the same method as duplicate samples. MS/MSD samples for soils typically do not require submitting additional sample volume but should be listed on the chain-of-custody form as required for that sample. One MS/MSD sample should be analyzed for every 20 samples submitted to the lab.

6.5 Field Documentation

Summary of field measurements and sampling activities will be recorded in a bound field logbook or log sheets, and entries must contain accurate and inclusive documentation of project activities as described in SOP-03 "Field Notes and Documentation". Entries will be made using permanent waterproof ink, and erasures are not permitted. Errors will be single-lined out, should not be obscured, and initialed and dated. The person making the entries will sign at the end of each day's entry, and a new page will be started for each day of sampling. The following entries will be made:

- General descriptions of weather conditions
- Location of each sampling point
- Data and time of sample collection
- The type of QC sample collected and the method of collection
- Field measurements made, including the date and time of measurements
- Calibration and/or checks of field instruments
- Reference to GPS and photographs
- Date and time of equipment decontamination
- Field observations and descriptions of problems encountered

Photographs may be required at some of the sampling locations and should include a general site location photo and a close-up of the sample or sample location. The photo location and number will be recorded on the field log sheets. The sample location coordinates will be recorded via GPS instruments at the time of sampling.

If required, soil lithologies will be logged at the time of sample collection using the Unified Soil Classification System Standard D 2487-92, developed by ASTM. Classification will include grain size, sorting, and plasticity among others and will be recorded on a separate log sheet. Observations of soil horizons or changes in soil characteristics as observed in the excavation will be recorded. SOP-12 “Soil and Rock Descriptions” further defines the characteristics to be described during soil logging.

6.6 QA/QC Review

Final data reported by the laboratories will undergo review by a QA oversight contractor under the direction of ARC. The purpose of analytical data verification/validation is to review data for completeness and confirm that requested methods and procedures were followed as required by this Work Plan and the QAPP. The outcome of the verification/validation process is to qualify data results that may be inaccurate due to data quality limitations (e.g., contaminated blanks, exceedance of sample holding times, or lab control standards (“LCS”) outside acceptable limits).

Level II Data *verification* will be completed on eighty percent (80%) of all project samples and includes review of the following measures:

- Sample holding times,
- Accuracy (by evaluating MS/MSD and LCS recovery),
- Precision (by evaluating field and lab duplicate results),
- Blank contamination,
- Surrogate compound recoveries,
- Chain-of-custody, and
- Case narrative.

Level IV data *validation* will be completed on the remaining 20 percent (20%) of samples that, in addition to the verification review listed above, will include a review of all raw laboratory data and calculations such as:

- Initial and continuing instrument calibration logs,
- Interference check samples,
- Reporting limits and sample recovery summaries, and
- Sample preparation and analytical run logs,

Analytical results will be evaluated during the verification/validation review of data received from the laboratories, and will also include a completeness check to ensure that all data has been properly loaded into the database used for report generation. Data that fail to meet the QA objectives for the characterization of background materials associated with the Yerington Mine Site will be qualified as to usability and potential low or high bias. The review of analytical data will follow the basic guidance provided in the National Functional Guidelines for Data Review, unless specified otherwise.

SECTION 7.0
DATA MANAGEMENT

Data generated during implementation of this Pit Lake RI Work Plan will be managed in accordance with the Draft DMP for the Site dated April 24, 2007. The DMP is meant to supplement the requirements and specifications stated in the field sampling and analysis plan (Section 4.0) and the QAPP. The DMP provides the processes and guidelines for sample tracking, storage, access, delivery, and reporting of new chemical analytical, geologic, biologic and spatial data generated by investigation operations. Additionally, the DMP addresses the management of historical data. Key data management objectives are identified and listed below.

- Provide data users with tools that allow simple and rapid access to stored data of various types;
- Provide methods of data entry and data loading with known accuracy and efficiency;
- Apply well-documented data validation modifications to the electronic database;
- Manage sample data using a unique sample identification number;
- Establish a sample inventory of new data and provide methods of sample inventory reconciliation;
- Store and provide sample-specific attributes, including location identifier, sample type, sample media, depth, date, and target study area;
- Provide reporting and delivery formats from a single database source to support data analysis, site characterization, risk assessment, modeling, and spatial analysis;
- Provide the ability to electronically compare results to project-specific reference or screening criteria; and
- Identify needs for incorporating historical data and establish a database of this information when possible; otherwise, establish a data inventory plan that identifies and catalogues historical data not suited for database entry.

SECTION 8.0
HEALTH AND SAFETY

All field activities will be conducted in accordance with the revised Health and Safety Plan ("HASP") for the Site (Brown and Caldwell 2007b). The HASP identifies, evaluates and prescribes control measures for health and safety hazards, including radiological hazards, and describes emergency response procedures for the Site. HASP implementation and compliance is the responsibility of Brown and Caldwell, with ARC taking an oversight and compliance assurance role. Copies of the HASP are located at the Site, in ARC's La Palma, California office, and in Brown and Caldwell's Carson City, Nevada office. The HASP includes:

- Safety and health risk or hazard analysis;
- Employee training requirements;
- Personal protective equipment (PPE);
- Medical surveillance;
- Site control measures (including dust control);
- Decontamination procedures; and
- Emergency response.

The HASP includes a section for Site characterization and analysis that would identify specific Site hazards and aid in determining appropriate control procedures. Required information for Site characterization and analysis includes:

- Description of the response activity or job tasks to be performed;
- Duration of the planned employee activity;
- Site topography and accessibility by air and roads;
- Identified safety and health hazards;
- Hazardous substance dispersion pathways; and
- Emergency response capabilities.

8.1 Training

All contractors will receive applicable training, as outlined in 29 CFR 1910.120(e) and as stated in the HASP. Site-specific training will be covered at the pre-entry briefing, with an initial Site tour and review of Site conditions and hazards. Records of pre-entry briefings will be maintained at the project site. Elements to be covered in site-specific training include:

- persons responsible for site-safety,
- site-specific safety and health hazards,
- use of PPE,
- work practices,
- engineering controls,
- major tasks,
- decontamination procedures and emergency response.

Other required training, depending on the particular activity or level of involvement, includes OSHA 40-hour training and annual 8-hour refresher courses. All employees shall receive specific training about the hazards of working around water and the additional safety precautions required including the proper use of PFDs and/or body positioning systems, basic water rescue procedures, and safe work practices. Other training may include, but is not limited to, competent personnel training for excavations and confined space. Copies of Site personnel OSHA certificates will be maintained at the project site and in employee personnel records.

8.2 Personal Protective Equipment

Minimum PPE requirements while performing the sampling task or other field activities outlines in this Work Plan include:

- Hard hat
- Safety glasses
- Steel-toe boots

- High-visibility clothing or reflective vest
- Nitrile and/or leather work gloves (as needed)

Additional PPE may be required depending on the work task and may include, but is not limited to, respirators, goggles, chemical protective suits, life jackets, fall protection or hearing protection. The use of respiratory protection is not anticipated to be necessary for the field activities identified in this Pit Lake RI Work Plan, but each situation will be evaluated individually based on equipment used, location, and general field conditions. These items will be reviewed in a pre-start safety review that includes the Project Manager, field staff and the Site Safety Officer. If sufficient potential exists, all field personnel will be issued fit-tested respirators and monitoring will be conducted to determine actual dust or contaminant concentrations in the air. Actual use of respirators will only be required if concentrations exceed OSHA permissible exposure limits (“PEL”). Further detail on the use and selection of respirators is provided in the HASP.

8.3 Ground Disturbance Safety Requirements

All drilling or other activities that results in ground disturbance must be evaluated for potential buried utilities that could interfere or create a safety hazard. Utility Service Alert (USA North) is the public underground utility location service for northern Nevada. The planned work area must be marked on the ground in white paint and a verbal description of the location or address must be provided to USA North at least 48 hours prior to the start of work. Additionally, a private locating service should be used to physically survey the planned work area in order to identify buried utilities that may not be registered with the public service, such as privately owned water lines, tanks or other buried materials.

8.4 Working-Near-Water Safety Procedures

Working on or around the pit lake is a water hazard that requires additional safety precautions. Working near water is primarily defined as that work which involves a potential danger of drowning. Evaluation as to whether work could represent a danger of drowning will be done on a site-specific basis. As a guide, it is generally considered that work conducted within six feet of water that is more than three feet deep or has a soft bottom of sufficient thickness to become an entrapment hazard can pose a danger of drowning. Use of fall protection systems (including guard rails and lifelines) may replace the need for personal flotation devices, rescue skiffs and other work near water health and safety procedure requirements.

All work near water will be done following BP's safety guidance document "*Guidance on Practice for Design and Construction Activities Adjacent to or In Water Bodies in Conduct of Remediation or On-shore Decommissioning Activities.*" General safety precautions that will be observed while working around water include:

- All workers shall have immediate access to emergency communications such as radio communications and/or cell phones.
- The use of a buddy system should be maintained in areas with water-related-hazards. Never enter a water body, no matter how shallow, or walk on a synthetic liner around water without another person close by.
- Have Personal Flotation Devices ("PFDs") available at the work site and within ready access. A PFD vest should be worn by personnel if they are working in a boat on open water, standing on unstable ground, on a potentially slippery liner, or near water that is greater than 3 feet deep. A "throwing ring" or other retrieval floatation device must be immediately available for use if rescue becomes necessary and shall have a minimum 90 foot retrieval line. PFDs must meet U.S. Coast Guard safety ratings (Types III and V).
- In general, fall protection systems may be used in place of PFD vests and other work near water controls. Examples include guard rails, fall arrest or body positioning systems, and lifelines. If a body positioning belt and lifeline is used, a second person must be in possession of the rope at all times or the rope must be tied of to a secure base and a firm tension shall be maintained such that the worker is not pulled off balance but is prevented from falling into the water.
- Should a person fall into water or have water splashed onto them, an emergency fresh water supply must be available for shower and eye wash capabilities. A portable emergency eyewash station shall be kept in the field vehicle which shall be positioned as close as possible to the work area. If the sample location is in the middle of the pond, several bottles of saline eyewash solutions shall be carried with the field team. Full body wash capabilities will be provided by the availability of several 5-gallon water jugs which can be used as an impromptu shower until the person can be transported to the site safety shower located in the lab building.

8.5 Boating Safety Procedures

When boarding a small boat, the Site worker will be sure that the boat is secure. With one hand on the boat, quickly lower yourself straight down into the center of the boat. A life preserver should be worn. If others are boarding, have them step along the fore-and-aft centerline of the boat while you hold the boat in place along the pier. Avoid carrying anything aboard. Step down into the boat and load the items off the pier, or have someone hand them to you one by one.

Amount and location of weight (persons and gear: the movable ballast) is critical for capsize protection. In a small utility boat, keep weight toward the middle, both fore-and-aft and side-to-side. If you see waves approaching, take them on the bow. Overloading a small boat inhibits its ability to rise to oncoming waves. Less freeboard means less clearance above the water's surface to prevent swamping. All craft must be operated within the boat manufacturers weight limits.

<u>Boat Safety Equipment</u>

- All persons on the boat will wear a U.S. Coast Guard approved Type III personal flotation vest. The Type II vests (typically orange chest type) are not recommended because they are difficult to work in. In addition, throwable Type IV devices will be readily available for use.
- At least one 1A-10BC Type U.S. Coast Guard approved hand-held portable fire extinguisher will be on the boat, readily available for use.
- Visual Distress Signal Flares and a battery operated light will be in good working order and readily available on the boat.
- A sound-producing distress signal, either bell, whistle, or horn, will be in good working order and readily available on the boat.
- A first aid kit will be available on the boat.
- All boat fuel (gasoline) will be contained in engine manufacturer's approved containers that supply fuel to the engine via neoprene fuel lines. No fuel transfers between containers are to be conducted aboard the boat.
- A secondary means of propulsion will be available on the boat (oars or paddle).
- A boat hook, anchors, and proper mooring lines will be available on the boat.

Safe Boating Operations

- All boats will be properly registered for use in waterways of local, state, and federal jurisdictions, and boat trailers and towing vehicles will be properly licensed and in good working order.
- The boat will only be operated by experienced personnel, preferably someone who has completed a boating safety courses.
- The boat will be operated in a safe manner and all waterway regulations will be obeyed.
- No smoking or alcoholic beverages are permitted on the boat.
- No recreational equipment for fishing, hunting, water skiing, or SCUBA diving will be allowed on the boat unless specifically authorized as part of the work-related equipment.

8.6 Job Safety Analysis

Job Safety Analysis ("JSA") is a tool used to identify hazards associated with all aspects of a specific task, and the preventive actions that can be implemented to minimize the hazards. Control of the hazards can be accomplished by a) elimination of the task, b) use of engineering controls to reduce exposure to the hazard, or c) use of PPE to protect personnel from injury.

A summary of potential hazards for the tasks listed in Section 5.0 is provided in Table 8-1.

Table 8-1. Job Safety Analysis Summary

Field Activities	Potential Hazards
1. Borehole drilling and well installation	▪ Drilling into underground utilities or striking overhead lines or objects with drill mast. ▪ Injury to hearing from noise. ▪ Inhalation hazards from dust from drilling and well construction activities. ▪ Physical injury from moving parts of machinery, hydraulic fluids, handling drill pipe. ▪ Hazards working near pit highwalls including rock fall, wall failure, unprotected fall hazards.
2. Groundwater sampling	▪ Skin irritation from dermal or eye contact with groundwater. ▪ Slipping or falling on wet ground surface or drilling platform. ▪ Burn or corrosion from sample preservatives. ▪ Lifting and ergonomic hazards from lifting sample pump and sample cooler

Table 8-1. Job Safety Analysis Summary - Continued	
Field Activities	**Potential Hazards**
3. Pit Lake water level measurements	▪ Working near water (shoreline), possible drowning hazard ▪ Hazards working near pit highwalls including rock fall, wall failure, unprotected fall hazards.
4. Seep flow measurements and sampling	▪ Pit highwall hazards. ▪ Open water boating hazards: drowning, hypothermia if wet, high waves if weather or highwall failure.
5. Shoreline meteorological station setup and data collection	▪ Physical hazards from hand tools, power tools, mobile equipment during installation.
6. Mid-lake depth specific water sampling and monitoring	▪ Open water boating hazards: drowning, hypothermia if wet, high waves if weather or highwall failure.
7. Submerged sediment sampling by gravity core	▪ Physical hazards operating coring equipment, generator, hand tools power tools. ▪ Back strain working in awkward positions ▪ Open water boating hazards: drowning, hypothermia if wet, high waves if weather or highwall failure.
8. Surface/shallow water sample collection	▪ Working near water (shoreline), possible drowning hazard
9. Biological habitat survey	▪ Falling hazard working near top of pit wall ▪ Pit highwall hazards: rock fall, slope failure, bench failure ▪ Working near or on open water: drowning, hypothermia
10. Pit highwall geotechnical evaluation	▪ If drilling is done, hazards from underground utilities or overhead power lines ▪ Pit highwall hazards: rock fall, slope failure, bench failure, unstable ground surface
11. General Activities	▪ Heat stress due to high ambient temperature, improper clothing, lack of ventilation, lack of water, or lack of shade; or ▪ Hypothermia or frostbite due to low ambient temperature, improper clothing, damp or wet clothing, or lack of source for heat. ▪ Sunburn from lack of shade or improper clothing. ▪ Biological hazard from contact with spiders, insects or reptiles.
12. Unsafe conditions	▪ Unexpected hazardous conditions such as wind, rain, snow, fire, earthquake, or other natural disaster can occur.

Comprehensive JSAs will be completed for all field activities before the work is initiated, and will be developed by field staff and the Site Safety Officer. All field staff and sub-contractors will review the JSA prior to conducting the work, and throughout the work to identify new hazards or controls. Task-specific JSAs are to be kept on-site at all times.

SECTION 9.0
REFERENCES

Allison, J.D., D.S. Brown, and K.H. Novo-Gradac, 1993, *MINTEQA2 – A geochemical assessment model for environmental systems*, Center for Exposure Assessment Modeling, U.S. EPA, Environmental Research Laboratory, College Station Road, Athens, GA.

Atkins, D., Kempton, J. H., Martin, T., and Maley, P., 1997, *Limnological conditions in three existing Nevada pit lakes: Observations and modeling using CE-QUAL-W2*. Fourth International Conference on Acid Rock Drainage, Proceedings Vol. II, p. 697-713.

Brown and Caldwell, 2005a, *Hydrogeologic Framework Assessment North of the Anaconda Mine Site. Yerington Mine Site, Lyon County, Nevada.* Prepared for Atlantic Richfield Company. Prepared by Brown and Caldwell, Carson City, Nevada.

Brown and Caldwell, 2005b, *Data Summary Report for Process Areas Groundwater Conditions. Yerington Mine Site, Lyon County, Nevada.* Prepared for Atlantic Richfield Company. Prepared by Brown and Caldwell, Carson City, Nevada.

Brown and Caldwell, 2006b, *Third Quarter 2006 Air Quality Monitoring Report. Yerington Mine Site, Lyon County, Nevada.* Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2007a, *Second-Step Hydrogeologic Framework Assessment Work Plan. Yerington Mine Site, Lyon County, Nevada*. Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2007b, *Site-wide Health and Safety Plan, Yerington Mine Site, Lyon County, Nevada.* Prepared for the Atlantic Richfield Company.

Carten, R.B., 1986, *Sodium-calcium metasomatism: chemical, temporal, and spatial relationships at the Yerington, Nevada Porphyry Copper Deposit*: Economic Geology, Vol. 81, p. 1495-1519.

Christensen, J. H., 2007: Regional Climate Projections. *Climate Change 2007: The Physical Science Basis*. Cambridge University Press, Cambridge, United Kingdom and New York, NY.

Cole T.M. and Wells, S.A., 2002, CE_QUAL_W2: *A two-dimensional, laterally averaged, hydrodynamic and water quality model, Version 3.1 (User Manual).* Prepared for U.S. Army Corps of Engineers, Washington DC.

Davis, A. and L.E. Eary. 1997. *Pit lake water quality in the western United States: An analysis of chemogenetic trends*. Mining Engineering *6:* 98-102.

Dingman, S. L., 1994, *Physical Hydrology*: MacMillan, NY, 575 p.

Driscoll, Fletcher G., 1986, *Groundwater and Wells, 2nd Edition*. U.S. Filter/Johnson Screens, St. Paul, MN.

Environmental Standards, Inc. (ESI) and Brown and Caldwell, 2007, *Quality Assurance Project Plan, Yerington Mine Site, Revision 1*. Prepared for the Atlantic Richfield Company.

EPA, 1989, *Risk Assessment Guidance for Superfund (RAGS):Volume 1-Human Health Evaluation Manual, Interim Final.* Office of Emergency and Remedial Response, Washington, DC.

EPA, 1992, *Ground Water Issue: Behavior of Metals in Soil*. Office of Solid Waste and Emergency Response, Washington DC. EPA/540/S-92/0185. October.

EPA, 1996, *Ground Water Issue, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, by R.W. Puls and M.J. Barcelona. Office of Research and Development. EPA/540/S-95/504.

EPA, 2000, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).* EPA 402-R-97-016/NUREG-1575.

EPA, 2001, *Performing Quality Flow Measurements at Mine Sites.* EPA/600/R-01/043, Science Application International Corporation, September.

EPA, 2002a, *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.* EPA-540/R-01/008, Washington D.C.

EPA, 2002b, *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers.* Ground Water Forum Issue Paper by D. Yeskis and B. Zovala. Office of Solid Waste and Emergency Response. EPA 542-S-02-001.

EPA, 2004, *Multi-Agency Radiological Laboratory Analytical Protocols Manual.* EPA 402-B-04-001A-C. Washington DC.

EPA, 2006a, *Guidance on Systematic Planning Using the Data Quality Objectives Process*. QA/G-4. Office of Environmental Information, Washington DC. EPA/240/B-06/001.

EPA, 2006b, *Data Quality Assessment: Statistical Methods for Practitioners EPA QA/G-9S*. EPA/240/B-06/003. Office of Environmental Information, Washington D.C. February.

EPA, 2007, *Administrative Order for the Remedial Investigation and Feasibility Study. In the matter of Anaconda / Yerington Mine Site, Yerington, Lyon County, Nevada. Atlantic Richfield, Respondent. U.S. EPA Region 9, Docket No. 9-2007-0005. Proceeding under Section 106(a) of CERCLA, as amended, 42 USC § 9606(a).* Including Attachment A: Scope of Work for the Remedial Investigations/Feasibility Studies Continued Response Action. January.

Geomega, 2003, *Evaluation of Expected Pit Lake Conditions, Main and North Pits, Getchell Mine.* Prepared for Getchell Gold Corporation. June.

Gill, Donald K., 1951, *Groundwater at the Yerington Mine, Lyon County, Nevada*. Prepared for the Anaconda Mining Company. March.

Hamblin, P. F., Stevens, C. L. and Lawrence, G. A., 1999, *Simulation of vertical transport in mining pit lakes*. Journal of Hydraulic Engineering, v. 125, p. 1029-1038

Harbeck, G. E., 1962, *A practical field technique for measuring reservoir evaporation utilizing mass transfer theory*. U. S. Geological Survey Professional Paper 272-E.

Hershey, R. L., and Miller, G. C., 1996, *Limnology and water quality of the Yerington, Nevada porphyry-copper open pit mine lake*. Geological Society of America Abstracts with Programs, v. 28, p. A-528.

Hershey, R., 2002. *Hydrology and water quality of the Yerington pit lake*, In: Geological Society of Nevada 2002 Spring Field Trip Guidebook Special Publication No. 35, Jurassic Magmatism and Metal Deposits in Western Nevada, Yerington Mining District, Humboldt Mafic Complex, June 15-16, 2003, *Ed.* Bob Thomas, p. 93-98.

Hershey, R.L., 1997, *Geochemical modeling of the Arimetco Porphyry-Copper Open-Pit Mine Lake, Yerington, Nevada*. Nevada Water Resources Association Annual Conference, October 8-10, 1997, Elko, Nevada.

Hershey, R.L., and G.C. Miller, 1997, *Geochemical modeling of the Arimetco Porphyry-Copper Open-Pit Mine Lake, Yerington, Nevada*. American Chemical Society Abstracts, Part 1, 214th ACS National Meeting, September 7-11, 1997, Las Vegas, Nevada, p. GEOC 024.

Hershey, R.L., C. Papelis, and G. Miller, 1998, *Analysis of sediments from a copper rich pit lake using scanning electron microscopy / energy dispersive x-rays*. 1998 Conference on Hazardous Waste Research, Abstracts Book, Snowbird Utah, sponsored by the Great Plains/Rocky Mountain Hazardous Substance Research Center, Manhattan, Kansas, p. 19.

Hershey, R.L., C. Papelis, and G.C. Miller, 2000, *Geochemical Model of the Arimetco Pit Lake, Yerington, Nevada*. Workshop on the Characterization, Modeling, Remediation, and Monitoring of Pit Lakes, Program Agenda, Abstracts and Bios, Presentations, *sponsored by* U.S. Environmental Protection Agency, April 4-6, 2000, Reno, Nevada, p. 61.

Hutchinson, G. E., 1975, *A Treatise on Limnology*. v. 1, Chapter 7, Wiley and Sons.

Huxel C.J., 1969, *Water resources and development in Mason Valley, Lyon and Mineral Counties, Nevada, 1948-65*. State of Nevada Department of Conservation and Natural Resources, Division of Water Resources, Water Resources Bulletin No. 38.

Imberger, J., and Patterson, J., 1990, *Physical limnology*. Advances in Applied Mechanics, 27, 303-475.

Integral Consulting Inc., Foxfire Scientific and Brown and Caldwell, 2007, *Draft Revised Conceptual Site Model, Yerington Mine Site, Nevada.* Prepared for Atlantic Richfield Company.

JCPDS, 1993, *Mineral Powder Diffraction File Databook: Sets 1-42*. International Centre for Diffraction Data. Swathmore, PA.

Jewell, P.W., 1999, *Stratification and Geochemical Trends in the Yerington Pit Mine Lake, Lyon County, Nevada*. Prepared for Arimetco Inc.

Kaplan, D.I. and S.M. Serkiz, 2000, *Quantification of Thorium and Uranium Sorption of Contaminated Sediments.* U.S. Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge TN. 37831-0062.

Kempton, H., 1996, Unpublished report from PTI Environmental Services to Santa Fe Pacific Gold Corporation on chemical composition, limnology, and ecology of three existing Nevada pit lakes (PTI project No. CA1Q0601).

Klaff, J., 2002, *Limnology: Inland Water Ecosystems*, p. 438-439, Prentice Hall, NY.

Lyons, W.B., Doyle, G.A., Peterson, R.C., and Swanson, E.E., 1994, *The limnology of future pit lakes in Nevada: The importance of shape*, in Tailings and Mine Waste '94: Balkema, Rotterdam, ISBN 95 5410 3647, p. 245-248.

McCutcheon, S. C., Martin, J. L., and Barnwell, Jr., T. O., 1993, Water quality, in *Handbook of Hydrology*, Maidment, D. R., ed., McGraw Hill, p. 11.1-11.73.

Miller, G.C. and R.L. Hershey, 1998, *Sulfate in Pit Lakes*. 1998 Conference on Hazardous Waste Research, Abstracts Book, Snowbird Utah, sponsored by the Great Plains / Rocky Mountain Hazardous Substance Research Center, Manhattan, Kansas, p. 22.

Miller, G.C., Lyons, W.B. and Davis, A., 1996, *Understanding the water quality of pit Lakes*. Environmental Science & Technology, 30, 3, 118-123.

Parkhurst, D.L., 1995, *User's guide to PHREEQC - A computer program for speciation, reaction-path, advective-transport, and inverse geochemical calculations*. U. S. Geological Survey Water Resources Investigations 95-4227, 143 p.

Pond, S., and Pickard, G. L., 1983, *Introductory dynamical oceanography*. Pergamon Press, Oxford.

Plummer, L.N., Prestemon, E.C., and Parkhurst, D.L., 1994, *An interactive code (NETPATH) for modeling NET geochemical reactions along a flow PATH--version 2.0*. U.S. Geological Survey Water-Resources Investigations Report 94-4169, 130 p.

Price, J. G., Shevenell, L., Henry C. D., Rigby J. G., Christensen, L., Lecher, P. J., Desilets, M., Fields, R., Driesner, D., Durbin W., and Lombardo, W., 1995, *Water quality at inactive and abandoned mines in Nevada*. Report of a cooperative project among state agencies: Nevada Bureau of Mines and Geology Open-File Report 95-4, 72 p.

Proffett, J.M., Jr., and Dilles, J. H., 1984, *Geologic map of the Yerington district, Nevada*. Nevada Bureau of Mines and Geology Map 77, scale 1:24,000.

Regonda, S.K., and coauthors, 2005: *Seasonal cycle shifts in hydroclimatology over the western United States*. Journal of Climate, 18, 372-384.

Schindler, D.W., 1977, *Evolution of phosphorus limitations in lakes*, Science, v. 195, p. 260-262.

Seitz, H. R., Van Denburgh, A. S., and La Camera, R. J., 1982, *Ground-water quality downgradient from copper-ore milling wastes at Weed Heights, Lyon County, Nevada*. U. S. Geological Survey Open File Report 80-1217, 48 p.

Sigg, L., Sturm, M. and Kistler, K., 1987, *Vertical transport of heavy metals by settling particles in Lake Zurich*. Limnology and Oceanography, v. 32, p. 112-130.

Stevens, C. L., and Lawrence, G. A., 1998, *Stability and meromixis in a water filled mine pit.* Limnology and Oceanography, v. 43, p. 946-954.

Stumm, W. and Morgan, 1996, *Aquatic Chemistry*, Wiley and Sons, New York, 1022 p.

Stevens, C. L., and Lawrence, G. A., 1998, *Stability and meromixis in a water filled mine pit.* Limnology and Oceanography, v. 43, p. 946-954.

Wiemeyer S.N. Tuttle, P.L. and Higgins, D.K., 2004, *Assessment of Wildlife Hazards Associated with Mine Pit Lakes*. Environmental Contaminants Program Off Refuge Investigations Sub-Activity (Project ID: 1F34). U.S. Fish and Wildlife Service Region 1. July.

WRCC, 2007, Yerington, Nevada (269229): Period NCDC 1971-2000 Monthly Normals. Western Regional Climate Center. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nv9229.